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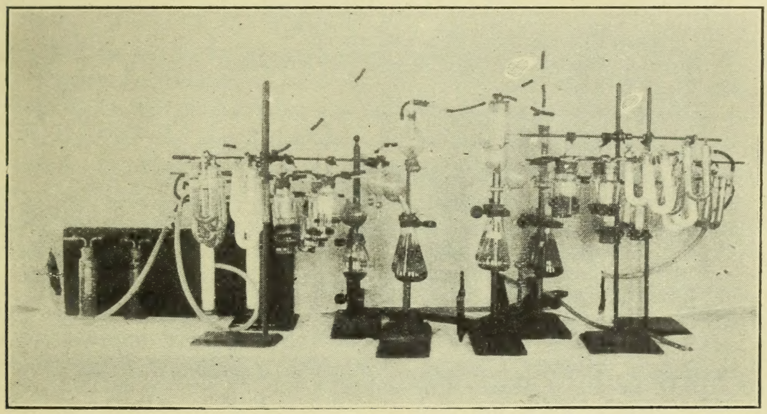

An Eight-unit CO_2 Apparatus

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SOIL CARBONATES
A NEW METHOD OF DETERMINATION

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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

SOIL CARBONATES

A NEW METHOD OF DETERMINATION

The necessity of rapidly and accurately determining soil carbonates in a comprehensive set of field experiments involving the use of light and heavy applications of lime, and lime supplemented by both light and heavy manure treatments, was responsible for investigations leading to the adoption of the method described in the latter part of this paper.

Hall[1] states, "In the analysis of a soil, without doubt the most important figure is the proportion of calcium carbonate." There has been proposed, however, no method sufficiently accurate and applicable to both light and heavy occurrences of carbonates to be adopted in detail as official by the Association of Official Agricultural Chemists. Lipman[2], reporting, in 1908, as Associate Referee for Soils to the above mentioned Association, states, "Unfortunately, there is no unanimity of opinion among chemists as to methods best adapted for the work."

The objects sought in this investigation were to determine: (1) The mineral acid least active upon soil organic matter and a concentration adapted to all occurrences; (2) whether the determination could be made by ordinary laboratory equipment without application of heat.

LITERATURE

METHODS FOR MISCELLANEOUS MATERIALS

Most of the methods advanced for the determination of of CO_2 in miscellaneous materials are based upon the liberation of CO_2 by acids of different strengths, aided by application of heat. The acids usually suggested are sulphuric, hydrochloric or nitric. The liberated CO_2 is estimated volumetrically by titration of an absorbent solution or gravimetrically by gain or loss in weight.

Gooch[3] accomplished the determination by means of the test tube device of Kreider[4], the residual CO_2 being forced out of the few c.c. of solution by air. Fresenius[5], Treadwell and Hall[6], and Glossen[7] heat with an excess of HCl to determine CO_2 in minerals, while Olsen[8] for the same material specifies either HCl, HNO_3 or H_2SO_4. Hillebrand[9] states that siderite and dolomite do not react completely with acids in cold and for total carbonates directs boiling with 1-1 HCl. Occurrences of CO_2 in substances such as bone are determined by Fresenius[10], quoting Scheibler[11], by the evolution of CO_2 at normal temperature and displacement through pressure resulting from the reaction, correcting for CO_2 absorption in the liberating acid. Dietrich[12] observed the necessity of correction for CO_2 absorbed by the acid in liberating flask, in the above method. J. Russ[13] first suggested the use of H_3PO_4 for determination of mineral carbonates and its use to differentiate between organic and inorganic carbon in steel work was noted by Morgan[14].

METHODS ADAPTED TO SOILS

In determining soil carbonates, Hopkins and Pettit[15] boil and estimate CO_2 evolved by absorption, noting charge in volume of absorbent. Lincoln and Walton[16] recommend boiling for 3 minutes. The Brown-Escombe double titration method was adapted to soils by Amos[17], who boiled with 1-1 H_2SO_4. Bowser[18] studied the Amos method upon synthetic soils, boiling with HCl. Wiley[19] recommends the Knorr method and also cites the Scheibler[11] method, using Bernard's calcimeter without heat, for approximations in chalky soils. Hall and Russell[20] use H_2SO_4 1-1 and liberate CO_2 at room temperature under vacuum, calculating CO_2 by means of formula. F. Sestini[21] digested with boiling acetic acid and determined CO_2 by calculation from CaO found in solution, while F. Mortinotti[22] suggested the use of neutral ammonium citrate solution. Mayer[23] used 1-2 glacial acetic acid because of its inactivity toward ferrous carbonate and Schütte[24] extracted with hot dilute HCl and determined CO_2 equivalent to dissolved lime. Distillation of ammonium carbonate formed by reaction of soil carbonates with added ammonium chloride was suggested by Stutzer and Harleb[25]. Successive grindings of soil with small amounts of water and digestion for 1¼-1½ hour with 30% acetic acid was proposed by Vant Kruijs[26]. The Belgian[27] method quoted by Wiley[28] consists of working soil with water to expel CO_2, washing soil into 300 c.c. flask, CO_2 being liberated by acid and collected, no reference to heat being quoted. Decrease in strength of acid and heating to 50°C under partial vacuum was advocated by Marr[29]. The Marr method was investigated and recommended by Gaither[30] in a comprehensive study of Ohio soils, correlating the acid litmus test with negative evolutions of CO_2 by the Marr method.

Wiley[31], quoting Van Bemmelen's[32] method for humus by calculation from organic carbon, states that small charges of 3 to 5 grams are used in a small flask in determining mineral carbonates, sulphuric or citric acid being used at room temperature for liberation of the gas; and data are given to show action of dilute acids when heated in contact with organic matter, on three types of carbonate-free soil.

Schenke[32a] ignited soil and then determined the amount of CO_2 taken up from contact with solution of ammonium carbonate.

CO_2 EVOLUTION AS MEASURE OF SOIL ACIDITY

Tacke[33] in his method for soil acidity determines the amount of CO_2 evolved from an excess of suspended $CaCO_3$, agitating at room temperature for 3 hours and displacing CO_2 by current of hydrogen. Wheeler, Hartwell and Sargent[34] modified Tacke's method by boiling the soil in contact with $CaCO_3$. Süchting[35] modified Tacke's method by introducing a definite amount of $CaCO_3$ and determining the re-

sidual carbonate CO_2 by addition of acid, subsequent to removal of CO_2 liberated by action of soil acids upon added carbonate, the reaction being at room temperature and a current of hydrogen used as in Tacke's method.

COMPARISON OF ACTION OF DIFFERENT ACIDS ON CO_2-FREE SOIL

During the winter of 1910, while at the Pennsylvania Station, the senior author adopted a suggestion from Dr. C. W. Stoddart and discontinued the use of HC1 in favor of H_3PO_4 in the determination of soil carbonates, thereby simplifying the CO_2 apparatus by eliminating the silver sulphate tube.

The following table shows the comparative action of H_2SO_4, HC1 and H_3PO_4 of three strengths, upon boiling for periods of thirty minutes, the first minute's evolution being noted in each case. The soil used was a fairly fertile loam of decided acidity and with a CO_2 content of .0196% m. f. basis by the method described in this bulletin. Inspection of Table I shows the superiority of H_3PO_4.

TABLE I—50 *grams of moist soil dried at 40°C to remove CO_2 and digested at boiling—fairly fertile loam soil.*

Acid	Strength	Gms. CO_2 evolved 1st min.	Gms. CO_2 evolved subsequent 29 min.	Total gms. CO_2 evolved 30 min.	Per cent (on soil basis) evolved 1st min.	Per cent (on soil basis) evolved subsequent 29 min.	Total per cent CO_2 evolved 30 min.
HCl	1-5	.0452	.0164	.0616	.0904	.0328	.1232
	1-5	.0448	.0153	.0601	.0896	.0306	.1202
							.1216
HCl	1-10	.0386	.0210	.0596	.0772	.0420	.1192
	1-10	.0351	.0224	.0575	.0702	.0448	.1150
							.1171
HCl	1-15	.0295	.0241	.0536	.0590	.0482	.1072
	1-15	.0308	.0224	.0532	.0602	.0448	.1050
							.1061
H_2SO_4	1-5	.0443	.0208	.0651	.0886	.0416	.1302
	1-5	.0420	.0259	.0679	.0840	.0518	.1358
							.1330
H_2SO_4	1-10	.0461	.0210	.0671	.0922	.0420	.1342
	1-10	.0431	.0248	.0679	.0862	.0496	.1358
							.1350
H_2SO_4	1-15	.0390	.0235	.0625	.0780	.0470	.1250
	1-15	.0369	.0237	.0606	.0738	.0474	.1212
							.1231
H_3PO_4	1-5	.0378	.0114	.0492	.0756	.0228	.0984
	1-5	.0415	.0083	.0498	.0830	.0166	.0996
							.0990
H_3PO_4	1-10	.0360	.0116	.0476	.0720	.0232	.0952
	1-10	.0358	.0120	.0478	.0716	.0240	.0956
							.0954
H_3PO_4	1-15	.0281	.0170	.0451	.0562	.0340	.0902
	1-15	.0308	.0163	.0471	.0616	.0326	.0942
							.0922

After it was determined that H_3PO_4 is the least active of the three most adaptable acids, the activity of 1-15 H_3PO_4 toward organic matter on an original loam soil was compared with the action on the carbonaceous material in the same soil subsequent to treatment with 1 per cent HCl and carbonated water to remove any carbonates. The data given in Table II and the contents of Table I show that there is decided action at the boiling point, even by boiling only one minute.

TABLE II—*CO_2 evolved from 50 grams original soil by boiling for 30 minutes with H_3PO_4, 1-15, and the same subsequent to elimination of carbonates*

Treatment	Grams CO_2 evolved	Per cent CO_2	Average per cent CO_2
Original soil air-dried	.0428 .0428 .0430 .0438	.0856 .0856 .0860 .0876	.0862
Extracted with 1% HCl in cold, air-dried	.0402 .0422 .0438	.0804 .0844 .0876	.0841
Extracted with 1% HCl in cold, dried at 40°C	.0427 .0447	.0854 .0894	.0874
Extracted with 1% HCl and then with carbonated water by agitation for 5½ hours, dried at 40°C	.0437 .0404	.0874 .0808	.0841
Extracted with carbonated water by agitation for 4 hours, dried at 40°C	.0335 .0454	.0670 .0908	.0784
Extracted with carbonated water by agitation for 16 hours, dried at 40°C	.0400 .0496	.0800 .0992	.0896

As a further check upon the data of Table II the soil was extracted with carbonated water and the carbonates determined in the extractant.

TABLE III—*Fifty grams moist soil agitated with current of CO_2, filtered and washed with carbonated water. Filtrate acidified with N-140 H_2SO_4 and excess acid titrated after boiling*

Time of contact	Grams $CaCO_3$ liberated	Grams CO_2 liberated	Per cent CO_2
30 min.	.0129 .0132	.0057 .0058	.0114 .0116
2 hrs.	.0146 .0159	.0064 .0070	.0128 .0140
4 hrs.	.0262 .0255	.0115 .0112	.0230 .0224

According to Cameron[36], a portion of the carbonates recovered would be the result of hydrolyzation of alkali silicates. The data of Tables I and II indicate that the evolution of CO_2 by heat is many times that accounted for by the aggregate of natural and synthetical mineral carbonates. Marr[37], studying the action of heat upon organic matter, presents the following table:

TABLE IV—*CO_2 evolved by boiling 10 grams CO_2-free soil, H_2SO_4 1-1, three successive 20-minute periods*

Origin of soil	1st 20 min.	2d 20 min.	3d 20 min.	Total CO_2 evolution from organic matter
	Grams	Grams	Grams	Grams
Ohio....................	.0422	.0224	.0211	.0857
Transvaal..............	.0316	.0171	.0136	.0623

The data presented in the foregoing tables prove beyond doubt the fallacy of boiling a soil with mineral acids for carbonate determinations.

Wiley[38] states, and quotes Veitch to the effect, that the boiling of alkaline soils with water will evolve CO_2. To the same effect Gaither[39] presents data upon a large number of soils, both acid and alkaline.

The acid loam soil of Table II was dried at 40°C to remove atmospheric CO_2 and boiled with CO_2-free water with the following results (50 gms. charge):

$$\left.\begin{array}{r} .0037 \\ .0065 \\ .0027 \\ .0044 \\ .0054 \\ .0026 \end{array}\right\} .0042 \text{ grams } CO_2.$$

This shows either action of heat upon the soil organic matter or reaction between minute localized occurrences of soil acids and carbonates.

PREPARATION OF SOIL PRIOR TO ANALYSIS

Subsequent to determining the superiority of H_3PO_4, data were secured to learn the most favorable treatment of the soil samples prior to digestion. Moist soil freed of atmospheric CO_2 by suction gave identical results with air drying, while samples oven-dried at 40° C gave somewhat greater CO_2 evolution.

COMPARISON OF MARR METHOD WITH BOILING AND ROOM TEMPERATURE

Substituting H_3PO_4 for H_2SO_4, the Marr method was studied, as compared with digestion at room temperature and at boiling, using 25 grams of loam soil freed from carbonates by cold digestion with 1 per cent HCl_{46}.

TABLE V—*Effect of temperature upon action of H_3PO_4 on soil organic matter*

25-gram charge 30-min. aspiration, 1-50 H_3PO_4, 4 in. vac., room temperature	25-gram charge 30-min. aspiration, 1-15 H_3PO_4, 4 in. vac., room temperature	25-gram charge Marr method H_3PO_4, 1-15, 50° C, 4 in. vac., 30 min.	25-gram charge Boiling 30 minutes H_3PO_4, 1-15
Grams	Grams	Grams	Grams
.0028	.0046	.0128	.0326
.0026	.0046	.0118	.0340
.0028	.0044	.0186	
	.0058	.0156	
		.0106	
		.0168	
Av. .0027	Av. .0049	Av. .0144	Av. .0333
P. ct. .0104	P. ct. .0196	P. ct. .0576	P. ct. .1332

The above results show considerably less action on organic matter at 50° than that effected by boiling, but appreciably more than at room temperature. The same results were also found in the case of well-rotted barnyard manure and of barnyard soil. The addition of 48 tons per acre of manure was found to cause no increase in CO_2 evolution by treatment with 1-15 H_3PO_4 in the cold. Phosphoric acid 1-15 by volume in several trials on substances rich in organic matter gave but very slightly higher results than H_3PO_4, 1-50, while it was found that for pure carbonates of calcium and magnesium the greater strength was necessary for complete liberation of CO_2 within 30 minutes. *It should be noted that CO_2 evolutions from the usual charge of 5 gms. gave unweighable quantities of CO_2 evolved from 3 acid soils by 1-15 H_3PO_4 at room temperature.*

CARBONATE DETERMINATIONS IN SOILS, WITHOUT APPLICATION OF HEAT

In preparing soils for determinations of humus Grandeau[10], Hilgard[11], Huston and McBride[12], Pasturel[13], A. O. A. C. Official Method[14], Wiley[15], and Fraps[16] direct the use of a dilute HC1 solution at room temperature to eliminate carbonates of calcium and magnesium prior to digestion with ammonia. This agreement as to evolution of all calcium and magnesium carbonate CO_2 by dilute HC1, simplified the authors' problem to ascertaining whether dilute H_3PO_4 would liberate carbonates and if the CO_2 could be freed from solution without use of heat, most methods being hypotheticated upon the necessity of heat to expel the last traces of CO_2. Folin[17] describes a method for the determination of NH_3 in urine by freeing NH_3 with soda, without heat, and aspirating off the gas into standard acid. The method was further studied and modified by Steel & Giess[18] and Howe and Hawk[19]. The accuracy obtained in the manipulation of this method indicated that CO_2 might be aspirated under similar conditions. After preliminary work it was determined that 2 gms. of calcium carbonate and 2 gms. of magnesium carbonate were easily dissolved in 100 c. c. 1-15 H_3PO_4 and that *agitation with aspiration* would remove all CO_2. Four residues were tested for CO_2 subsequent to 30 minutes' agitation and aspiration with 1-15 H_3PO_4 at room temperature by boiling, with negative results. The following CO_2 results were obtained gravimetrically from Kaulbaum's C. P. calcium carbonate and Iceland spar, with constant agitation and aspiration for 30 minutes under slight vacuum without soil.

TABLE VI—*Analysis of C. P. $CaCO_3$*

Taken		Found
Grams CaCO	Grams CO_2	Grams CO_2
.4000	.1760	.1739
.4000	.1760	.1761
.4000	.1760	.1781
.4000	.1760	.1783
.4000	.1760	.1780
.2054	.0904	.0894
.1678	.0738	.0742
Average	.1492	.1497

Average difference + .0005 grams.

After the foregoing data were secured the work was duplicated by introducing three distinct types of surface soil and a red clay subsoil from a cellar digging. In view of the fact that Findlay and Creigh-

ton[50] observed that suspended silt increases solubility of CO_2 at normal pressure, one very silty soil was included among the surface soils.

Trials upon C. P. $CaCO_3$ with 50 gms. of soil without agitation and with agitation at 5-minute intervals, gave repeatedly low results.

TABLE VII—*CO_2 recovered from* .3000 *gram Kalbaum's C. P. $CaCO_3$ aspirated for* 30 *minutes, slight vacuum, with constant vigorous agitation,* 1-15 *H_3PO_4*

Soil	Gms. CO_2 original soil	Gms. CO_2 added	Gms. CO_2 theory	Gms. CO_2 found	Gms. CO_2 difference	Difference per cent CO_2 soil basis
50 gms.	.0091	.1320		.1405		
loam soil	.0085	.1320		.1421		
	.0078	.1320		.1408		
	.0109	.1320		.1400		
	Av.0091	Av.1320	Av.1411	Av. .1409	—.0002	—.0004
50 gms.	.0056	.1320		.1384		
silty Ford	.0043	.1320		.1364		
soil	.0050	.1320		.1383		
	.0045	.1320		.1370		
	Av.0049	Av.1320	Av.1369	Av. .1375	+.0006	+.0012
50 gms.	.0033	.1320		.1347		
red sandy	.0014	.1320		.1354		
Keffer soil	.0027	.1320		.1332		
	.0021	.1320		.1335		
	Av.0024	Av.1320	Av.1344	Av. .1342	—.0002	—.0004
50 gms.	.0006	.1320		.1315		
red clay	.0009	.1320		.1325		
subsoil		.1320		.1338		
	Av.0008	Av.1320	Av.1328	Av. .1326	—.0002	—.0004

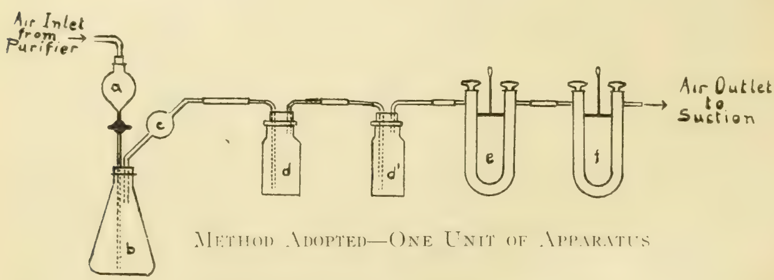
Referring again to Table V, it will be noted that the 1-15 H_3PO_4 gave slightly higher results on the CO_2-free soil than 1-50 H_3PO_4. In practice it was found that the 1-15 was required for very heavy occurrence of carbonate. Very slight action was found, however, upon well-rotted manure and barnyard soil from H_3PO_4 acid, 1-15. The action of H_3PO_4 1-15 in the cold is much less than would be permitted as laboratory error of duplication in routine investigational work. However, in view of the results above stated and the results of Marr, Wiley and Gaither, previously cited, the authors advance and strongly advocate the following suggestion: Where two or more soils are to be studied comparatively, or when the *absolute* carbonate CO_2 content be desired, blank determinations be run upon the soil, after treatment as suggested by Fraps[46], for humus, increasing the strength of the HC1 to 2 per cent where the carbonate occurrence is

heavy and filtering by suction on a 9 cm. filter with Büchner funnel, which is very rapid. The blank obtained from this chlorine-free acid-washed soil should be deducted from the determination on the untreated soil, as measuring the degree of activity of the acid upon soil organic matter.

ACTION OF H_3PO_4 ON OTHER CARBONATES

Frear[31], studying action of various strengths of HCl, with and without heat upon dolomite and siderite, notes inactivity of the two minerals named and cites the surprising fact in the case of siderite that when in contact in the cold for 10-15 minutes the evolution of CO_2 is 2.6 times that secured from boiling for one minute. He makes reference to the need of vigorous agitation. Samples of siderite secured from the collection of Dr. Wait, of the University of Tennessee, were analyzed and gave with 1-50 H_3PO_4 and 30 minutes digestion, and agitation, at room temperature, .0023 gm. CO_2, which was increased to .0258 gm. on boiling, using a charge of .5 gm. while .1650 gm. CO_2 were secured from the same charge by heating with HCl 1-5. A 1-per cent HCl aspirated with agitation at room temperature for 30 minutes gave .0044 gms. CO_2 and .0658 gm. upon boiling. On testing the siderite used, considerable calcium was found, and it is quite possible that trace of CO_2 found could be attributed to that source, making the action of the acid on the iron carbonate entirely negative.

A Knox dolomite found to have 44.10 per cent CO_2, as calculated from CaO and MgO determinations of W. H. MacIntire, and 44.22 per cent from CO_2 determination with heat by L. G. Willis, gave 42.4 per cent CO_2 by aspirating 30 minutes with constant shaking, using 1-15 H_3PO_4 at room temperature. A further aspiration of 15 minutes gave a full recovery of CO_2. A 5-gm. charge of manganese spar aspirated at room temperature for 30 minutes with 1-per cent H_3PO_4 gave .0141 gm. of CO_2 and .0687 gm. when boiled with the same acid. This mineral showed an absence of calcium carbonate when tested.



METHOD ADOPTED—ONE UNIT OF APPARATUS

METHOD ADOPTED

The following method as used in this laboratory has given entire satisfaction, having been used upon 135 soil samples which were under absolute laboratory control and covering light and heavy occurrences of CO_2. Where evolution of CO_2 is not greater than .2000 gm., 50 gms. of soil may be used, the amount of soil for the charge being decreased with an increasing percentage of CO_2. The evolution is kept to this amount in order that the soda-lime tubes may be effective for more determinations. A separatory funnel (a) connected with purifying apparatus leads through a two-holed rubber stopper to the bottom of a 300-c. c. Erlenmeyer flask (b). Through the second hole is inserted a bulb tube (c) leading to two purifying bottles (d and d) containing concentrated H_2SO_4. To the second acid bottle is attached U tube (e) containing soda lime and this attached to tube (f) containing pumice stone saturated with concentrated H_2SO_4. The tube used is the modification described by W. H. MacIntire, Jour. Am. Chem. Socy., March, 1911. If volumetric determinations be desired, a Folin absorption tube or a tower containing glass beads may be used. After purifying the atmosphere of the apparatus, 60 to 100 c. c. of H_3PO_4, 1-15 CO_2-free, is added through the funnel and CO_2 drawn off at a *very slow* rate, with *constant agitation,* for 10 minutes. The second 10 minutes the rate is slightly increased, and during the third 10-minute period purified air is drawn fairly rapidly through the system. Slight vacuum should be maintained.

The essentials of the method are *very slow aspiration* at first, *constant agitation* and slight vacuum.

When charges of as much as 25 gms. are used, or if the soil be highly carbonaceous, determine and deduct blank on the soil, after eliminating CO_2, local citation 46.

It is good practice to have two soda-lime tubes in the train and discard the first when the second begins to gain. Experience has shown the inadvisability of using one tube alone after the heating phenomenon is noticed as far as the curve of the tube. In an endeavor to eliminate the labor incident to shaking by hand, the authors tried various schemes and different-shaped containers for charges, bringing air in through mercury and zinc bottoms, but none gave satisfactory results, save shaking by hand.

Due to the elimination of condensers and silver sulphate tubes, the apparatus can be made very compact, and as many units as desired may be used.

Mr. Willis has ingeniously coupled eight units together by clamping stands, and the entire eight can be shaken by one person with ease by means of glass tubing for rollers. The 8-unit system occupies but 50 inches of desk space and with it two men can easily make 32 gravi-

metric determinations daily, one person purifying apparatus and weighing charges, the other weighing two sets of tubes. Where several units compose a system, two Muencke's wash bottles should be used, followed by two tall soda-lime tubes, containing cotton at outlet, for air purification. The system is illustrated on the title page of this bulletin.

SUMMARY AND CONCLUSIONS

1. Phosphoric acid is, of the available mineral acids, the least active upon soil organic matter.

2. Phosphoric acid at room temperature acts but slightly on soils rich in organic matter.

3. Phosphoric acid 1-15 at room temperature liberates all of the CO_2 from $CaCO_3$ and $MgCO_3$ in soils, and the CO_2 evolved can be collected by aspiration with suction, either gravimetrically or volumetrically.

4. If *finely ground*, limestone and dolomite can be determined with or without soil, under the above conditions.

5. Constant agitation is essential to complete CO_2 liberation.

6. Dilute phosphoric acid in the cold is not appreciably active upon ferrous carbonate and but slightly so on manganese carbonate.

7. In comparative CO_2 studies, a blank should be run upon the soil subsequent to its being freed of carbonates, and as correction made for the action of the acid on organic matter.

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Stub

BULLETIN

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COWPEA AND MILLET HAY

Sown at last cultivation of Irish potatoes and harvested before potatoes were dug

NUMBER 101 OCTOBER 1913

THE RATIONAL IMPROVEMENT OF CUMBERLAND PLATEAU SOILS

CONCLUSIONS FROM SIX YEARS OF FIELD EXPERIMENTS WITH VARIOUS FARM CROPS

BY

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KNOXVILLE, TENNESSEE

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The Experiment Station building, containing the offices and laboratories, and the plant house and part of the Horticultural Department, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy building, etc., are located one mile west of the University on the Kingston Pike. The fruit farm is adjacent to the Industrial School and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

PREFACE

The Cumberland Plateau has an area in Tennessee of about 5000 square miles. The average elevation is in the neighborhood of 1800 feet, or nearly 1000 feet above either the East Tennessee Valley on the east or the Highland Rim on the west. This section is practically undeveloped from an agricultural point of view, and lands are very cheap—$2.00 to $10.00 per acre. The soils are fine sandy loams which support a varied forest growth but, unaided, are light producers under cultivation. The cultivated soils are apt to be shallow, 2 to 5 feet being a common depth to the underlying sandstone. The rainfall, however, is ample, being in the neighborhood of 55 inches per annum, and is well distributed throughout the year, and crops appear to suffer less here from dry weather than on the deep limestone soils of the East Tennessee Valley.

At Erasmus, Cumberland Co., with an altitude of nearly 1900 feet, the average date of the last killing frost in the spring is April 21, and of the first killing frost in the fall October 15.

The experimental work done by the Station for the past six years in this section was under the care of Mr. J. E. Converse, to whom thanks are due for efficient service and for valuable suggestions.

Numerous experimental results with various crops have been reported in detail in Bulletins 86 and 92, which may be obtained upon request.

THE RATIONAL IMPROVEMENT OF CUMBERLAND PLATEAU SOILS

Conclusions from Six Years of Field Experiments with Various Farm Crops

PRINCIPLES OF SOIL FERTILITY WITH SPECIAL REFERENCE TO THE CUMBERLAND PLATEAU

THE PLANT-FOOD ELEMENTS

Plants need food of different kinds, very much as do animals. That is, a plant will starve if deprived of any one of several substances in the soil, just as a man will starve if he tries to live on fat meat alone, or on starch alone, or on sugar alone, or, for that matter, on all three of these articles of food, because they lack the element that makes blood and lean meat and which is found in eggs, milk, beans, and the like. To state the case another way, a person to be well fed, not only must get enough food to satisfy his hunger, but also the food must contain in proper amount the elements needed to renew all parts of the body. In like manner, plants, to be well nourished, require an abundance of each of a number of elements.

The elements necessary

The elements found in the soil which are necessary to plants are nitrogen, phosphorus, calcium, potassium, magnesium, sulphur, and iron. Those that come wholly from air and water are carbon, hydrogen, and oxygen. The latter group makes up the bulk of the dry substance of plants, or 90 to 99 parts out of 100. The element nitrogen can be given an intermediate place between the two groups, because the original source of the soil nitrogen is the air. Also certain kinds of plants, the legumes, are able to utilize atmospheric nitrogen, though this is done indirectly, through the nodule-forming bacteria found in their roots.

To the farmer the discovery of the elements that plants must have meant much, for as long as they were unknown there was no way to tell exactly what could be used to help make poor land rich. Since this knowledge was obtained the world has been searched for minerals and refuse that supply these elements; soils have been analyzed to find out how much of each they contain; and it is now possible to take almost any soil and make it fertile.

The four elements of most importance

Of the seven soil elements mentioned, only four have been found to be especially important in practical farming. That is, they are the only ones which are apt to be deficient in the soil, and which generally make the difference between a rich and a poor soil, so far as plant food is concerned. These four elements are nitrogen, phosphorus, calcium, and potassium. The last three are sometimes called the "minerals" and are generally referred to under the names of "phosphoric acid," "lime," and "potash."

Principles of soil fertility must be applied to the Plateau

One of the prime objects of this bulletin is to show the special plant-food needs of the Cumberland Plateau soils, what fertilizers to buy, and, as far as possible, how much to use on different crops in order to get the best practical results. The writer may be allowed to say that he believes that this part of the State will become, in the course of time, a prosperous agricultural section; but this condition will be brought about only when the people understand the fundamental principles of soil fertility and apply them with special regard to their soil needs.

PHOSPHORIC ACID AND LIME NATURALLY VERY DEFICIENT IN PLATEAU SOILS

Chemical analysis tells much about a soil's supply of plant food, and if the evidence furnished by the analysis is supported by the results of field trials there can be little doubt as to the correctness of the conclusions. In the case of the Cumberland Plateau soils we have both kinds of evidence to prove that they are naturally very poor in two important mineral substances, phosphoric acid and lime. According to the chemical analyses made at this Station, an average acre of Cumberland County soil to the depth of one foot contains only 1600 pounds of phosphoric acid and 3100 pounds of lime that can be dissolved out by the aid of strong, hot hydrochloric acid, as compared with 8000 pounds of phosphoric acid and 11000 pounds of lime in the rich Central Basin soil. The results of experiments made chiefly in Cumberland County have demonstrated repeatedly that lime and phosphoric acid are greatly needed. Since the relative value of these two elements is of practical importance, the writer will state at the outset that for Plateau soils phosphoric acid is more necessary than lime, but the need of both is so great that there should be no occasion for surprise that in the past many farmers have become discouraged and failed in the attempt to get satisfactory crops from such a soil. Fortunately, these two substances are easily obtained, and can be profitably used from the outset. Also the writer

will add that the soils of the greater portion of the eastern United States are deficient in these same elements, and that little more will be found to be required by the Plateau soils than should be used elsewhere outside of a few favored localities.

HOW MUCH AND WHAT KIND OF LIME TO USE

Ground limestone, fresh burnt lime, air-slaked lime, and wood ashes may be used for liming the land. Any one of them will "sweeten" the soil; and the Plateau soils are generally "sour," a condition that is unfavorable to most farm crops. A reasonable application of ground limestone for this section is 2 tons per acre; and if it be evenly distributed this amount will probably be ample for 5, or perhaps 10, years. One ton of burnt lime is equal to 2 tons of the ground limestone, and may be used to advantage where the hauling is an important item. About 1 1-3 ton of air-slaked lime is equal to 1 ton when fresh-burnt, and about 3 tons of wood ashes are required to equal 2 tons of the ground limestone. Any of these materials can be advantageously applied for almost any crop. The crops most benefited are the legumes, such as clovers, cowpeas, etc., but according to our field experiments corn, sorghum, millet, oats, and the like are nearly always helped to a marked extent, so that the expense of liming is often more than met the first year by the increased yeilds.

Why is lime little used?

The question may now arise, If lime is highly beneficial to Plateau soils, why has it not been extensively used? There are, doubtless, several reasons, such as the expense and labor of hauling and applying, but in particular a lack of knowledge in regard to its true value. The fact must be remembered that in addition to making "sour" land "sweet" lime adds only one element of plant food to the soil, and that it does not take the place of phosphoric acid, or potash, or nitrogen. The writer has little doubt that if lime were the only necessity it would have been extensively used long ago, but the fact that other things were needed complicated the matter and obscured its true value. Therefore, lime the land, but do not expect it to take entirely the place of phosphate, of manure, of soil-improving crops, or any good method of soil improvement. For further details and experimental data of different kinds, reference may be had to Bulletin 97 of the Tennessee Experiment Station, "Liming for Tennessee Soils."

PHOSPHATES

Phosphoric acid is the valuable constituent of a number of commercial materials which are known as phosphates. Some kind of phosphate is a necessity in order to lay the foundation for a fertile

and durable Plateau soil; and acid phosphate is now advised as the most profitable for general use. Either Thomas slag phosphate or bone meal might be used, but they are too expensive. Raw phosphate rock is recommended by some, but, according to numerous experiments by the Station, its effect is uncertain and, if the land be limed, acid phosphate is apt to surpass it in profitableness. Unlike an application of lime, which need be made only once in several years, acid phosphate should be used in small quantity and applied for almost every crop. Two to three hundred pounds per acre is a practical amount for a common farm crop, such as corn, sorghum, millet, cowpeas, etc., and will more than replace the phosphoric acid which the crop removes.

Composition and grades of acid phosphate

Since acid phosphate is the basis material of the commercial fertilizer mixtures, its composition and properties should be understood by every farmer. Briefly stated, acid phosphate is made by mixing about equal parts by weight of ground phosphate rock and sulphuric acid. The acid unites with the lime of the rock phosphate and forms the sulphate of lime, or land plaster, which makes up about one-half of the acid phosphate. In addition, the phosphoric acid is changed from insoluble to soluble forms, so that plants can readily make use of it. Fertilizer dealers generally handle two grades of acid phosphate. One is guaranteed to contain 16 per cent of available phosphoric acid, and the other is a "low-grade," guaranteed to contain 14 per cent of available phosphoric acid. The "high-grade," with 16 per cent guarantee, is nearly always the most economical to buy. In fact, the 14 per cent goods is apt to be made, in response to a demand for a cheap fertilizer, by mixing sand, soil, or some such material, with a high-grade goods to reduce it to a low-grade. Any such reduction costs something to make, and the freight on the material added must be paid, so that for these, as well as other reasons that may be thought of, the really dear and least profitable kind is the low-grade phosphate.

Some properties of acid phosphate

If kept under cover acid phosphate can be held over for any length of time, as it does not lose strength on standing. It should not be mixed with either lime or ashes, but even then its value is by no means destroyed. It is not lost from the soil by leaching, but in the course of a little time combines with lime, iron, or other bases in the soil, which reduce the readiness with which plants can make use of it, and hence one reason for the advice to make a light dressing to suit each crop. Wherever needed the effect of an application of acid phosphate is especially noticeable in the increased production of grain and fruit, though an increase of stem and leaf growth is also marked. Only a relatively small quantity of phosphoric

acid is needed even by a large crop, but a great deficiency in the soil, such as is the case on the Plateau, will almost make successful farming impossible until the deficiency is remedied.

Not enough manure

At this point some one is sure to think of a vegetable garden or other piece of land which was made highly productive by the application of manure and where neither commercial phosphate nor lime had ever been used. Manure is a complete fertilizer, containing lime, phosphoric acid, potash, and nitrogen. It is also an alkaline substance, and tends, therefore, to "sweeten" a soil. The great value of manure is unquestioned. If every farmer had all he was willing to haul for, say, four or five miles, the soil fertility problem would be solved; but unfortunately nothing of the kind is the case, either here or anywhere else, except in the neighborhood of some town or city. Furthermore, if the manure could be gotten, a good liming of the land and an application of phosphate would be profitable at the outset of the soil upbuilding, for the manure would give better returns and clover could be grown at once. The writer recalls a very successful farmer who bought land with similar deficiencies to those of the Plateau. He brought it up to a high state of productiveness in the course of his lifetime by buying corn from his neighbors and feeding it, along with whatever else he could raise, to cattle. He considered the manure as about the chief profit, and thereby succeeded in enriching his land. In this case the necessary phosphoric acid was obtained in the corn which grew on other lands, which were therefore impoverished. All the manure is needed that can be gotten, but to get the crops that can be fed to make the manure both lime and phosphate are very important.

POTASH

Potash is not much needed by the Plateau soils, so that if the major part of the crops grown be fed on the farm and the manure returned to the land, little attention need be given to this element. At the same time the soils are only moderately well supplied and if large crops, by the aid of liming, phosphating, and good methods of culture, be grown, and especially if crops like Irish potatoes be raised for shipment, then potash salts should be used in moderate quantity along with acid phosphate.

Muriate of potash

The cheapest of the commercial salts is the muriate of potash, which retails at nearly 3 cents per pound. It contains about 50 pounds of potash to the 100, so that potash is one of the cheap elements which can be profitably supplied whenever needed.

Soy-Bean Hay

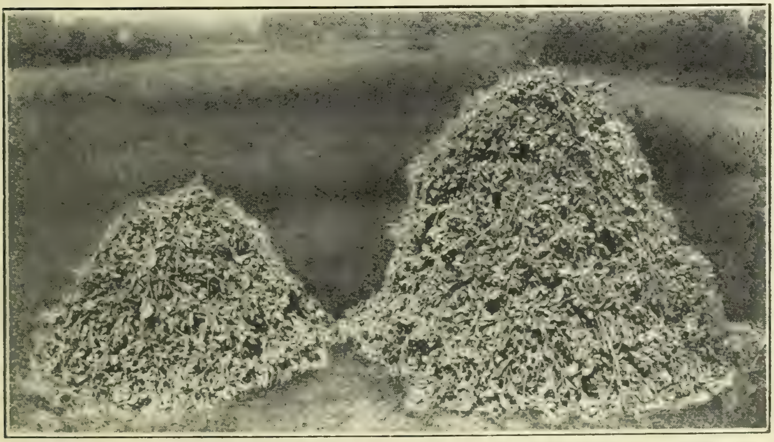
From Fertilizer Experiments on the Lemmert Farm, Cumberland County

No Fertilizer

0.46 ton hay per acre

Phosphate and Potash

1.16 ton hay per acre



Lime Alone

0.66 ton hay per acre

Phosphate, Potash and Lime

1.72 ton hay per acre

Wood ashes

Wood ashes contain about 5 pounds of potash to the 100, but if kept dry and unleached may contain twice this amount. Of course, in addition the wood ashes contain a large amount of lime—to which the writer would attribute its chief value—some phosphoric acid, and, in fact, all of the mineral elements of plant food.

NITROGEN

As a rule the most marked difference between rich and poor land or between "new" and "old" land lies in the content of nitrogen and humus, which are abundant in the rich soil but deficient in the poor soil.

Cost of nitrogen

Nitrogen is by far the most expensive to buy of the plant food elements. A pound of available phosphoric acid costs at the present time about 5 cents; a pound of potash costs nearly 6 cents; but a pound of nitrogen costs in the neighborhood of 20 cents. Moreover, plants require two or three times as much nitrogen as they do of phosphoric acid. For example, the nitrogen needed in the production of a bushel of corn would cost about 33½ cents, while the phosphoric acid would cost only 3 cents and the potash 7½ cents. This high cost of nitrogen prohibits more than a small amount being used for field crops and limits the amount that can be used profitably on even high-priced garden crops. It is this high cost of nitrogen that prevents the so-called "complete fertilizer" from being well balanced and containing its due proportion of nitrogen. In fact, 100 pounds of the average complete fertilizer, as commonly sold on the market, contains enough phosphoric acid for 18 bushels of corn, but only enough nitrogen for one bushel. With these facts before us, and also in view of the poverty in nitrogen of nearly all long-cultivated soils, not only on the Plateau but everywhere in the Eastern States, it is evident that the problem of really building up the soil in this element must be solved in some way other than by buying it in commercial fertilizer form. To understand that fertilizers in and of themselves must fail to keep up soil fertility, because they do not furnish enough nitrogen, is very important and explains why they have so often fallen into disrepute.

Nitrogenous materials

There are a number of nitrogenous materials which are much used for fertilizer purposes, such as ammonium sulphate, dried blood, and tankage, but the two that are the most easily obtained and are in other respects best adapted to general use are nitrate of soda and cotton-seed meal. Nitrate of soda contains 15 pounds and "prime" cotton-seed meal about 6½ pounds of nitrogen per 100. For Plateau soils neither is advised to be used alone, but only in connection with an application of acid phosphate.

LEGUMES AS A SOURCE OF NITROGEN

Fortunately there is a family of plants that is able to get nitrogen from the air through the aid of bacteria which live in their roots. This family is known as legumes. Those of most importance are as follows: Red clover, alsike clover, white clover, crimson clover, Japan clover, alfalfa, sweet clover, cowpeas, soy beans, garden beans and peas, and vetches. A complete fertilizer for these crops need not contain nitrogen; hence, the usual recommendation is, after the land has been limed, to use a mixture of only acid phosphate and muriate of potash. For Cumberland Plateau soils the following is a moderate application for an acre of land:

200 lbs. high-grade acid phosphate
20 lbs. muriate of potash

The two ingredients should be well mixed by shoveling them together so that both may be applied at the same time.

SOIL INOCULATION

On the roots of all kinds of legumes are normally found small growths resembling warts, but which are called "nodules." These nodules are produced by exceedingly small forms of plant life, the nodule-forming bacteria, which can be seen only by the aid of a powerful microscope. These bacteria take plant food of the various kinds needed from the root sap of the plants in which they live and in turn they supply the plant with more or less nitrogen, which they have the power to get from the air. If a legume be grown in a soil which does not contain these bacteria it can make use only of the soil supply of nitrogen, like other plants, such as corn or wheat. Clover, for instance, can enrich a soil in nitrogen only when the proper bacteria are present because the latter are the true nitrogen gatherers from the inexhaustible supply of the air. It has been found that widely different kinds of legumes require different bacteria. For example, cowpeas may thrive on a certain soil, the nodules proving that the right kind of bacteria are present, but alfalfa sown on the same soil may produce only yellow looking and unhealthy plants and no nodules be found even though the soil be limed and well fertilized. In such a case the proper bacteria must be supplied before alfalfa can be grown successfully. This is usually done by scattering 200 or 300 pounds of earth per acre, taken from some field where alfalfa was grown successfully and was well inoculated. Also, inoculation usually follows the repeated seeding of the legume desired, and for this reason a small amount of alfalfa or of sweet clover seed is sometimes advised to be sown with clover and grass.

Some precautions

In this connection there are a few precautions which should be mentioned. First, it is not worth while to inoculate soil in great need of lime and phosphate until these substances have been supplied. Second, direct rays of the sun can kill the germs, so that the best results are obtained if the inoculating soil be either drilled into the ground or scattered broadcast on a cloudy day and then harrowed in. Third, undesirable weed seeds may be brought to the land along with the desirable bacteria. It may also be mentioned that after a soil has once become thoroughly inoculated a second inoculation is seldom if ever needed.

The Plateau soils have proven rather poorly supplied with bacteria, and if any of the following crops be grown, soil inoculation may be required in order to get the best results: Vetch, crimson clover, soy beans, Canada field peas, sweet clover, and alfalfa. For the last two crops in particular inoculation should always precede the first seeding.

AZOTOBACTER

There is another and very important group of bacteria, which appear to be nearly everywhere, and which supply the soil with nitrogen from the air. They are called azotobacter. Unlike the nodule-forming kinds, azotobacter are independent of the higher forms of living plant life. The conditions favorable to their best development are abundant supplies of lime, phosphoric acid, air, and some kind of organic matter, such as would be furnished by rye or other green crop turned under, the carbon of which they use as a source of energy. Meadow land conditions seem to be favorable to them, for meadows are found to gain in nitrogen even when no legumes are present.

HUMUS

One of the soil constituents which are well known to decrease under usual cultivation is humus, as the dark-colored organic substances which result from the decay of vegetable matter, etc., are called. The value of vegetable matter in the soil is not apt to be overestimated, for the humus produced from it increases the water-holding capacity of the soil and improves the texture, so that the soil is less inclined to bake and be cloddy. Also its importance in connection with different kinds of necessary bacteria is very great.

GREEN-MANURE FARMING

The growing of a legume, to be turned under and followed with a money crop, is known as green-manure farming and has been practiced very successfully both in some parts of Europe and in this

country. New Jersey farmers have grown crimson clover to be turned under and followed with either potatoes or corn, not only getting large crops, but also building up the soil at the same time. Crimson clover is being grown in various parts of Tennessee and may be used to advantage on the Plateau, as soon as the soil conditions are made right. This includes liming and the use of the acid phosphate and muriate of potash mixture previously mentioned, and attention to the proper inoculation of the soil. Many soils, however, are too poor in vegetable matter for any of the clovers, in which case cowpeas followed by rye may be used as green-manure crops at first.

CROP ROTATION

A proper rotation, or change of crops, has much to do with soil fertility. In the most prosperous and longest organized farm communities definite crop rotations are followed year after year with little variation. The kind of crops grown must of course be suitable to the climate, the soil, and the market conditions, but there are certain essentials to be kept in mind.

Cultivated crops

There should be one or more cultivated crops in every rotation so that weeds may be kept in check or eradicated. Good crops for this purpose are Irish potatoes, cowpeas or soy beans, planted in rows, sorghum, and corn.

Grass and legumes

To put vegetable matter into the soil and increase its water-holding capacity and productiveness in general, a grass crop is very important. An essential for most soils, and for the old and worn Plateau soils in particular, is one or more leguminous crops to bring nitrogen from the air. For this purpose cowpeas are the easiest grown, but in order to be of much benefit the crop must be either pastured off or turned under. To prevent loss of nitrogen by leaching a winter cover crop of rye or wheat is necessary. This in turn could be grazed, but should be plowed under when about one foot high in preparation for a money crop, such as potatoes or corn. Soy beans resemble cowpeas as soil improvers, but neither is equal to red clover, which should be the one crop especially sought; for once the conditions for its satisfactory growth have been gotten the problem of getting at least moderately profitable crops of corn, potatoes, etc., has been solved.

A crop rotation for new land

Most of the Plateau section remains to be cleared, and there appears to the writer no reason why the new lands should not be put at once under a rotation that, with the aid of liming, phosphating, and the careful saving and use of farmyard manure, will maintain a high state of productiveness. Generally speaking a

long rotation, covering a period of five or more years, is better than a short two or three-year rotation. The following is given as an example of a good, practical rotation:

1st year—Corn, followed by cover crop of rye sown at last working.

2d year—Cowpeas or soy beans.

3d year—Rye or wheat.

4th year—Clover and grass (chiefly clover).

5th year—Clover and grass (chiefly grass).

This means that the cultivated part of the farm is divided into five fields and that each year, as soon as the rotation is fully going, there is one field in corn, one in cowpeas or soy beans, one in a small grain, one in first-year clover and grass, and one in second-year clover and grass. To suit potato growers the grass may be omitted and potatoes take the place of the second year's clover and grass.

For a complete scheme of crops to be grown in order to reach this rotation, and the fertilizers, etc., suggested, see page 135.

THE RELATION OF THE POTATO CROP TO SOIL IMPROVEMENT—WHAT MAY BE EXPECTED OF THE FERTILIZER

The Cumberland Plateau soils are mainly fine sandy loams. This kind of soil is easily cultivated, allows an excess of water to escape readily, is adapted to a great variety of crops, and contains enough clay to make it retentive of manure and fertilizer.

Conditions favorable to potatoes

From a physical point of view they are the best adapted of all the soils in the State to the production of Irish potatoes and resemble in this respect the celebrated potato soils of Northern Maine. The climatic conditions are also favorable to potato growing. There remains, therefore, only one serious problem, so far as the getting of yields is concerned, and that is the enrichment of the soil. Fortunately, this crop is one that can be liberally fertilized. It not only responds well to fertilizers, but also the value of the plant food removed by a bushel of potatoes is small as compared with the value of that removed by a grain crop. For example, a bushel of corn (grain only) contains about 22½ cents' worth of plant food, but a bushel of potatoes only 6½ cents' worth. The cultivation of this crop also leaves the soil in nice condition for a crop to follow, whether it be crimson clover to enrich the soil in nitrogen or a winter cereal, such as rye or wheat, to prevent the loss of plant food by leaching during the winter and early spring. There is, therefore, an opportunity to utilize potatoes both as a money crop and as a start toward building up the soil fertility.

Fertilizer for potatoes

From what has just been said, too much might be expected from the fertilizers which may be used, so that we need again a clear understanding of their capacity to enrich the soil.

According to the Station's experiments, a good, practical fertilizer mixture for one acre of potatoes is as follows:

300 lbs. high-grade acid phosphate.
50 lbs. muriate of potash.
400 lbs. cotton-seed meal.

Increase from fertilizer

Now, let us see what theoretical increase in yield may be expected from the 750-pound application. 400 pounds of cotton-seed meal contains as much nitrogen as is required in the production of 100 bushels of potatoes, but all the nitrogen applied is not taken up by the crop, and as a matter of fact an increase of 50 bushels would be considered high. This means that if the phosphate and potash supply be ample and the soil be poor in nitrogen, an increased yield of only 50 bushels could be expected even under very favorable seasonable and cultural conditions.

Let us suppose, on the other hand, that the nitrogen supply of the soil be good, and that the great need is phosphoric acid. In this case there is, according to theory, enough phosphoric acid supplied by the 300 pounds of acid phosphate for 500 bushels, but according to field trials only about one-third can be expected to be used by the immediate crop, so that an increase of 170 bushels might be obtained in reality. In a similar way it may be shown that there is enough potash for 80 bushels, but that only about two-thirds may be taken up by the crop for which it is applied.

As a matter of fact the 750 pounds per acre has, in our experiments in Cumberland County, given an increase in the neighborhood of 75 bushels over the unfertilized check plot. The soil cannot, therefore, be said to have been materially enriched in any element except phosphoric acid.

SOME RESULTS OF FIELD EXPERIMENTS

FERTILIZERS FOR IRISH POTATOES

QUANTITY OF COMPLETE FERTILIZER

Table I gives the results obtained in nine series of experiments conducted on as many different soils of varying fertility. The fertilizer used consisted of the mixture previously mentioned. The approximate cost of 750 pounds of the mixture was $9.90. In one-third of the trials this amount per acre proved more profitable than twice the quantity, and is recommened as a conservative application. 1,500 pounds per acre proved, however, to be on the average the more profitable, and would, of course, leave a larger residue for the benefit of the succeeding crop. The results were obtained in different seasons, but probably represent rather favorable conditions for this crop.

TABLE I—*Fertilizer experiments with Irish potatoes, testing two rates of application,* 750 *and* 1500 *pounds per acre, of a complete fertilizer—results of nine series, each conducted on a different farm*

Series	Yield per acre without fertilizer		Yield per acre with 750 lbs. complete fertilizer		Yield per acre with 1500 lbs complete fertilizer	
	Total	Salable	Total	Salable	Total	Salable
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
1	61	52	104	81	136	122
2	57	36	101	80	109	92
3	37	17	96	76	108	88
4	24	4	109	54	158	91
5	32	20	142	131	191	180
6	73	63	123	110	136	121
7	54	46	164	147	198	177
8	155	139	193	180	221	205
9	110	90	167	151	228	199
Average	67	52	133	112	165	142

COTTON-SEED MEAL VERSUS NITRATE OF SODA FOR POTATOES

Table II gives the results obtained on seven different farms where experiments were made to compare the effect of nitrogen from cotton-seed meal with that from nitrate of soda for Irish potatoes. 400 pounds of the meal was assumed to contain the same amount of nitrogen as 160 pounds of the nitrate. Acid phosphate and muriate of potash were used in every case in sufficient quantity to make the nitrogen fully effective. The averages of the series show that nitrate of soda was only slightly more efficient than the cotton-seed meal, the average total yield being 145 bushels where the nitrate was used, as compared with 140 bushels where meal was used; but the average quantity of salable potatoes was the same for each. Nitrate of soda has the advantage of being somewhat cheaper than cotton-seed meal, but the disadvantages that it cannot be so generally obtained, is apt to be lumpy and need pulverizing, and is preferably applied separately from the phosphate and potash as a surface dressing.

Typical Results from Experiments with Potatoes

No Fertilizer — 44 Bu. per acre

12 Tons Manure Per Acre — 130 Bu. per acre

12 Tons Manure and 600 Lbs. Acid Phosphate Per Acre — 179 Bu. per acre

FARMYARD MANURE ALONE AND REINFORCED WITH FERTILIZERS

Farmyard manure can be used with extra good chance of profit on the Irish potato crop. According to the results of Table III, 12 tons of manure per acre gave, as the average of six series of experiments, an increase of 92 bushels of salable potatoes, or 7 2-3 bushels per ton of manure. Farmyard manure is considered to be a complete and well-balanced fertilizer for a soil that is fairly well supplied with the mineral elements, phosphoric acid and potash, but for Plateau soils an additional supply of phosphoric acid in particular is needed in order to make manure most efficient. The average of five series of

TABLE 11—*Fertilizer experiments with Irish potatoes, with special reference to a comparison between cotton-seed meal and nitrate of soda as sources of nitrogen—results of seven series, each conducted on a different farm*

Series	Yield per acre without fertilizer		Yield per acre with phosphoric acid and potash No nitrogen		Yield per acre with phosphoric acid, potash and nitrogen from cotton-seed meal		Yield per acre with phosphoric acid, potash and nitrogen from nitrate of soda		Notes
	Total	Salable	Total	Salable	Total	Salable	Total	Salable	
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	
1	24	4	(33)	(6)	82	71	105	59	400 lbs. meal vs. 160 lbs. nitrate
2	32	20	93	82	162	150	156	146	400 " " 160 "
3	81	64	150	127	164	150	157	148	600 " " 240 "
4	73	63	96	84	130	115	129	116	450 " " 180 "
5	89	79	93	83	85	74	102	89	300 " " 120 "
6	155	137	167	152	179	164	190	177	800 " " 320 "
7	110	90	(153)	(131)	181	162	173	153	400 " " 160 "
Average	81	65	112	95	140	127	145	127	480 " " 192 "

TABLE III—*Fertilizer experiments with Irish potatoes.* ***Manure alone vs.*** *manure reinforced with commercial fertilizers—six series conducted on six different farms*

Series	Yield per acre without fertilizer		Yield per acre with 12 tons manure		Yield per acre with 12 tons manure and 600 lbs. acid phosphate		Yield per acre with 12 tons manure, 600 lbs. acid phosphate, 100 lbs. muriate of potash, and 320 lbs. nitrate of soda		Yield per acre with 12 tons manure, 600 lbs. acid phosphate, and 320 lbs. nitrate of soda	
	Total	Salable	Total	Salable	Total	Salable	Total	Salable	Total	Salable
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
1	50	45	153	126	212	179	...	...	...	...
2	42	22	195	150	...	...	315	266	...	...
3	24	4	196	140	248	208	286	251	286	254
4	32	20	128	116	209	201	215	206	...	...
5	110	90	212	193	237	213	244	228	242	223
6	83	62	109	76	139	111	159	127	145	114
Series 1-6 averaged	57	41	166	133	...	...	...	...	...	...
Series 1, 3-6 averaged	60	44	160	130	209	182	...	...	...	...
Series 2-6 averaged	58	40	168	135	...	...	244	216	...	...
Series 3, 5, 6 averaged	72	52	172	136	208	177	230	202	224	197

experiments gives an increase of 138 bushels of salable potatoes from an application of 12 tons of manure, reinforced with 600 pounds of acid phosphate, as compared with an increase of only 86 bushels from 12 tons of manure alone. As the average of three trials, the application of 320 pounds per acre of nitrate of soda, in addition to 12 tons of manure and 600 pounds of acid phosphate, resulted in a further increase of 20 bushels of salable potatoes per acre. The results of the experiments in which 100 pounds of muriate of potash per acre were used in connection with 600 pounds of acid phosphate and 320 pounds of muriate of potash as a supplement to the manure, are not favorable to the use of the potash salt.

VARIETY TRIALS OF IRISH POTATOES

Several variety trials were made with Irish potatoes, but they were neither as extensive nor as long continued as is necessary in order to get conclusive results, but the late white type are especially recommended. According to the results obtained, Burbank and Green Mountain were the best late varieties, and Early Rose and Irish Cobbler the best medium-early. Bliss Triumph was found to be one of the lowest yielders.

NORTHERN-GROWN VERSUS HOME-GROWN SEED

Five trials, in which five different varieties were represented, were made between Northern-grown and home-grown seed. The average yield for the Northern-grown seed was 58.7 bushels per acre and for the home-grown seed 63 bushels per acre. This outcome is in harmony with the results obtained elsewhere, which show that good-sized home-grown seed is superior to the Northern-grown seed. Mention should be made, however, of the fact that the continued planting of small seed is very apt to cause the variety to "run out," so that a very inferior strain is the result. On the other hand, the selection of good-sized seed potatoes from productive hills will have a strong tendency to improve the crop.

TIME OF APPLICATION OF NITRATE OF SODA

Nitrate of soda—value and properties

Nitrate of soda furnishes nitrogen in its most available form for plant-food purposes, especially for cereal crops. It is also about the cheapest commercial source of fertilizer nitrogen. These two reasons are sufficient to warrant the study on the part of every farmer of the most important principles concerning its use. Nitrate of soda is very readily soluble in water and may be lost from the soil by leaching, but this chance of loss is much less than

might be supposed, as the results of Table IV show. It may be decomposed and nitrogen be lost into the air by being mixed with acid phosphate, but in practice such loss is apt to be small. Nitrate takes up moisture from the air in considerable quantity, and the mixture with acid phosphate will, if sufficient nitrate be present, soon become sticky, so that there are two reasons against mixing acid phosphate and nitrate soda. Fertilizer manufacturers have found, however, that they could add a small amount to their mixture without bad results, and this is not an uncommon practice. Because of the chance of loss by leaching and of the possible bad results from mixing with other fertilizer materials, nitrate of soda is usually applied by itself as a top-dressing. The generally accepted rules in regard to its use are as follows:

Rules for use of nitrate

1. If the soil be poor in either phosphoric acid or potash, nitrate should not be used until the deficiency in these mineral elements be supplied. According to numerous trials on Highland Rim and Cumberland Plateau soils, 300 pounds of acid phosphate and 50 pounds of muriate of potash are ample to reinforce 160 pounds of nitrate.

2. For fall-sown small grains, a very light application—say 40 pounds per acre—may be made at the time of seeding, provided the soil be poor and there be some danger of the crop's freezing out; otherwise all of the nitrate is applied as soon as spring growth starts, or some time in March. For spring and summer crops the nitrate is applied as a top-dressing when the plants are small.

3. Nitrate should not be applied when the leaves of the plants are wet with rain or dew, as burning is apt to follow.

4. With light applications, up to, say, 200 pounds per acre, all the nitrate may be applied at one time, but with heavy applications one-half is often advised to be applied at an early stage of growth and the balance in ten days or two weeks.

EXPERIMENTAL EVIDENCE

For the reason that there is at the present time a wide difference between the recommendations of some writers in regard to the time at which nitrate should be applied, experiments were undertaken on this subject with two crops, corn and Irish potatoes. The soils used were, of course, deficient in nitrogen in each case, and phosphate and potash were applied in ample quantity to make the nitrate effective. Table IV gives the schemes followed and the results obtained as an average of several trials for each crop.

TABLE IV—*Experimental results relating to time of application of nitrate of soda*

Crop	Exp. No.	Amount of nitrate applied per acre	Time of application of nitrate	Yield per acre		Remarks
				Grain Bu.	Stover Ton	CORN
Corn	1	None	....	25.7	1.19	The average of three complete sets conducted on three different farms, each in a different section of the State.
	2	100 lbs.	When plants about 3 in. high	31.2	1.39	Phosphate and potash used on all plots alike.
	3	"	" " " 2 ft. "	31.4	1.32	
	4	"	" " " 3½ "	30.0	1.25	
	5	"	As soon as in tassel	24.8	1.26	
				Salable tubers Bu.	Culls Bu.	POTATOES
Irish potatoes	1	None	....	78	14	Average of four sets on four different farms, three on Cumberland Plateau and one on Highland Rim.
	2	320 lbs.	Mixed in row before planting	145	22	Phosphate and potash used in ample amount to balance nitrate.
	3	"	In one application as soon as plants came up	150	16	
	4	"	In two applications, ½ as soon as plants up and ½ about 12 days later.......	133	20	

DISCUSSION OF THE RESULTS

Early application best for corn

The results with the corn point very definitely to the application of the nitrate at an early stage of growth, the gain being greatest when the plants were from 3 inches to 2 feet high. Of special interest were the results following the application made at tasseling time, for in none of the three series from which the averages were obtained did any increase in yield of grain result from this time of application, the only apparent effect being a deeper green foliage.

Early application best for potatoes

The results of the experiments on Irish potatoes are of special interest, as three of the four sets were made on the fine sandy loams of the Plateau, which might be expected to suffer from leaching. In practically every one of the four sets nearly as good results as any were obtained when the nitrate was mixed with the phosphate and potash applied in the row before planting. This was rather unexpected, for the rainfall at this time of the year is heavy, so that loss of nitrate would be looked for. The results from applying one-half of the nitrate as a top-dressing when the plants were just coming up, and the balance in ten days or two weeks, were unfavorable to this method. As with the corn, the results are, therefore, decidedly in favor of an early application.

FERTILIZERS FOR CORN

PHOSPHATE AND POTASH

Corn is a very important crop, but one that is low-priced, so that the question as to the most profitable fertilzer is not always easy to answer. Fertilizer experiments covering every condition have not been possible, but considerable evidence has been obtained. With regard to phosphate, acid phosphate in moderate quantity, say 200 pounds to the acre, is recommended, and may be used by itself with as good a chance for profit as any other material or combination of materials of equal money value; it may even give greater profit, especially in the case of freshly cleared land. If a light dressing of manure can be made, then the plain acid phosphate is highly advisable as a supplement to the manure, which, as demonstrated in the potato experiments, is strengthened in its weakest point for soils like these. In a similar manner acid phosphate is recommended for a green-manure or pasture crop which is to be followed by corn, the one application in that case answering fairly well for the two crops.

The experimental results do not warrant anything more than a very light application of a potash salt, say, 10 pounds per acre of muriate of potash mixed with the acid phosphate.

CAN NITRATE OF SODA BE USED PROFITABLY FOR CORN?

We have now to consider the value of nitrogenous materials when used in combination with acid phosphate and muriate of potash. In particular, the question arises, Can nitrate of soda be used profitably for corn?

In order to answer this question field experiments have been conducted at various places in the State. In some instances the experiments have been rather extensive, embracing 25, and even 30, plots, some of which received no fertilizers, some only phosphate and potash, others only nitrate, and a fourth set receiving phosphate, potash, and nitrate. Such a series was conducted in Warren County for each of three seasons, 1908, 1911 and 1912. In Table V are presented the fertilizer scheme and the results of the series conducted in 1912 on the farm of A. P. Titsworth, in Warren County. This series is given by itself for the reason that the results are characteristic of those obtained from nitrating under very favorable seasonal and soil conditions. According to these experiments, the cost of nitrate for each bushel of increase produced by it was 32 cents for the 40-pound application for an acre, 31 cents for the 80-pound application, 37 cents for the 160-pound, and 46 cents for the 240-pound. Under less favorable conditions the increased yield proved insufficient to pay for the nitrate, and in very unfavorable seasons no increase in grain production was obtained. Evidently there is considerable risk run. All things considered, the margin of profit appears at the present time to be too small to permit the recommendation of nitrate of soda for the corn crop, except possibly a very light application under special conditions of nitrogen deficiency.

A COMPLETE FERTILIZER FOR VERY POOR SOILS

In order to get additional data with regard to a practical formula for corn, experiments were undertaken with three different mixtures, each of which was tested at three different rates. Table VI gives the average results of six sets of these trials, which were conducted in the seasons of 1907, 1910, and 1911. Each set was conducted on a different farm, and the unfertilized plots gave yields ranging from 6.3 to 24.1 bushels per acre, the average being 15.5 bushels per acre. The experiments were made, therefore, under strictly poor-land conditions, but such as are of common occurrence.

The three formulas used were as follows:

FORMULA 1

1200 lbs. high-grade acid phosphate
100 " muriate of potash
480 " cotton-seed meal

This mixture analyzes approximately—

11 per cent available phosphoric acid
1¾ " " nitrogen
3 " " potash

TABLE V—*Fertilizer experiments on corn, with special reference to nitrate of soda—experiments conducted on farm of A. P. Titsworth, Warren County*

Series	Phosphate and potash per acre	Application of nitrate and increased yields per acre											
		No nitrate		40 lbs. nitrate		80 lbs. nitrate		160 lbs. nitrate		240 lbs. nitrate		Average	
		Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
		Bu.	Ton	Bu.	Ton	Bu.	Ton	Bu.	Ton	Bu.	Ton	Bu.	Ton
1	No phosphate; no potash....	*	*	2.4	0.16	0.0	0.14	0.6	0.12	5.1	0.20	2.0	0.16
2	300 lbs. acid phosphate......	11.4	0.66	12.6	0.58	15.5	0.64	21.5	0.62	21.7	0.78	16.5	0.66
3	{ 300 lbs. acid phosphate.. } { 100 lbs. muriate of potash }	6.4	0.50	9.9	0.62	....	....	20.6	0.78	20.8	0.86	14.4	0.69
4	{ 150 lbs. acid phosphate.. } { 100 lbs. muriate of potash }	6.2	0.36	12.1	0.46	12.6	0.44	16.9	0.24	....	....	12.0	0.38
5	{ 600 lbs. acid phosphate.. } { 100 lbs. muriate of potash }	8.9	0.56	13.5	0.72	19.6	0.76	25.8	0.84	26.5	0.74	18.9	0.72
	Average of series 2, 3, and 5	8.2	0.52	12.0	0.60	15.9	0.61	21.2	0.62	23.0	0.79	....	....

*Average of five unfertilized plots, 36.5 bushels grain and 1.08 ton stover per acre.

FORMULA 2

1200 lbs. high-grade acid phosphate
100 " muriate of potash
720 " cotton-seed meal

This mixture analyzes approximately—

10 per cent available phosphoric acid
2½ " " nitrogen
3 " " potash

FORMULA 3

1200 lbs. high-grade acid phosphate
100 " muriate of potash
1440 " cotton-seed meal

This mixture analyzes approximately—

8 per cent available phosphoric acid
3½ " " nitrogen
2½ " " potash

OBJECTS IN VIEW

Attention is called to the fact that in the experiments the low rate for each formula—135 pounds of Formula 1, 150 pounds of Formula 2, and 200 pounds of Formula 3—contains the same quantity of acid phosphate, or about 90 pounds per acre; also each contains about 6¾ pounds of muriate of potash per acre; so that the differences are due entirely to a variation in the amount of cotton-seed meal used. In a similar manner, the medium rates of 202, 225, and 308 pounds each contained the same amounts of acid phosphate and muriate of potash; namely, 134 pounds of the former and 11 pounds of the latter per acre. In the heavy rates of 404, 450, and 617 pounds per acre the amount of acid phosphate for each was 270 pounds and of muriate of potash 22.5 pounds per acre. The experiments, therefore, resolve themselves into only two distinct objects; one to determine the proportion of cotton-seed meal which would be the most profitable to use with a given amount of the acid phosphate and muriate of potash, and the other to determine the quantity of the complete mixture which would be the most advisable to use. In all the trials the fertilizer was applied in the row and mixed with the soil by running a shovel plow through it before planting.

RESULTS OF EXPERIMENTS

The results of these experiments seem to justify the use of a complete fertilizer for corn on very poor soils like these. The largest gross profit was obtained where a medium application of 308 pounds per acre of Formula 3 was made. The second largest gross profit was obtained where the medium application of 225 pounds of Formula 2 was used. If the average gross profit of the three formulas be calculated, then Formula 3 ranks highest, with \$4.32 per acre; Formula 2 ranks second, with \$3.92 per acre; and Formula 1 ranks lowest,

TABLE VI—*Trials of three different fertilizer mixtures for corn—seasons of 1907-1912—average of six sets—four on Highland Rim and two on Cumberland Plateau*

Fertilizer used per acre	Yield per acre		Increase over unfertilized plots		Value of increase @ 60c per bu.	Cost of fertilizer	Cost of increase per bu.	Profit per acre from fertilizer
	Grain	Stover	Grain	Stover				
	Bu.	Ton	Bu.	Ton				
135 lbs. Fomula I..........	21.0	0.98	5.5	None	$3.30	$1.51	$0.27	$1.79
202 " " "..........	23.7	1.18	8.2	0.10	4.92	2.26	.27	2.66
404 " " "..........	29.3	1.40	13.8	0.32	8.28	4.52	.33	3.76
150 " " II..........	24.7	1.28	9.2	0.20	5.52	1.72	.19	3.80
225 " " "..........	27.6	1.29	12.1	0.21	7.26	2.59	.21	4.67
450 " " "..........	29.6	1.41	14.1	0.33	8.46	5.18	.37	3.28
206 " " III..........	25.2	1.27	9.7	0.19	5.82	2.50	.26	3.32
308 " " "	30.1	1.37	14.6	0.29	8.76	3.74	.26	5.02
617 " " "	35.7	1.49	20.2	0.41	12.12	7.50	.37	4.62
No fertilizer	15.5	1.08						

with an average profit of only $2.74 per acre. The question arises, however, Do the results justify the recommendation of Formula 3, which gave both highest yield and largest gross profits. In the writer's opinion they do not, for the reason that the margin of profit which can be attributed to the large proportion of cotton-seed meal in Formula 3 is too small to warrant the risks incurred. The moderate application of 225 pounds per acre of Formula 2 is, therefore, advised as both conservative and practicable. According to these experiments it raised the average yield of corn from 15.5 bushels to 27.6 bushels per acre, at a cost of only $2.59. It may be of interest to note that 225 pounds of Formula 2 contains as much phosphoric acid as is removed by the grain and stover of a 40-bushel crop, enough potash to replace that removed by 5½ bushels and nitrogen to equal that removed by only 3 bushels, the stover being included with the grain in each case.

VARIETIES OF CORN

Table VII gives the results obtained in the variety trials of corn. Hickory King, which was taken as the standard of comparison, is well adapted to this section. At the same time there are several other and somewhat earlier varieties which have done well, especially those which have been grown for a number of years on the Plateau and are known by local names, such as Rains, Ramsey, and Morrow. Leaming is an early variety that has given splendid results, and as it is a standard and well-established variety, like Hickory King, seed can be easily obtained in any quantity. Rank-growing and late varieties, such as Huffman, Webb's Improved Watson, Cocke's Prolific, and Albemarle Prolific, are evidently not adapted to the average soils. The last two mentioned may, however, be used for ensilage purposes on improved land.

TABLE VII—*Variety trials of corn on the Cumberland Plateau* (1907-1912)

Hickory King in comparison with—	Number of trials made	Number of trials in favor of Hickory King	Average yield in favor of (+) or against (—) Hickory King
			Bu.
Albemarle	7	7	+10.0
Iowa Silver Mine	5	3	+ 5.2
Leaming	14	8	+ 2.3
Morrow	6	4	+ 0.9
No. 182	3	2	+ 1.5
Rains	3	2	— 0.6
Ramsey	5	3	+ 1.9
Shepherd	2	2	+ 4.2
Webb's Improved Watson	7	7	+ 9.7

ALFALFA

The question of the adaptability of the Plateau to alfalfa is often asked. Alfalfa should be considered a rich-land rather than a poor-land crop and is, therefore, not naturally suited to this section. However, with proper attention to the requirements of this crop there does not appear to the writer any important reason why it can not be grown profitably to a limited extent. A fraction of an acre rather than acre lots is advised for initial tests.

Success with alfalfa has been found to depend largely on the fulfillment of the following conditions:

1. Thorough preparation of the soil, begun some months previous to seeding.

2. The cleansing of the soil from weeds by frequent harrowing, so that no weeds go to seed, at least during the summer when the alfalfa is sown.

3. A dressing of lime, either one ton of burnt lime or two tons of ground limestone per acre.

4. A heavy application of phosphate, say, under Plateau conditions, 1000 pounds of acid phosphate per acre, one-half applied before plowing and one-half afterward, to get it well mixed throughout the soil; also 100 pounds of muriate of potash is advised.

5. At least moderately heavy manuring, say not less than 12 tons of manure per acre, which should be done early in the summer so that weed seeds may sprout and be gotten rid of before seeding to alfalfa.

6. Inoculation of the soil, for which 400 pounds per acre of inoculated soil from an old alfalfa field is recommended.

7. Liberal seeding—24 to 30 pounds per acre of the best Kansas or Nebraska seed—to be done early in August.

8. Thorough harrowing of the alfalfa after each cutting in order to get rid of crab-grass, etc. This may be done with a disc harrow, but a specially constructed, spring-tooth harrow, such as is now on the market, has been found in the Station's trials to give better results than any other implement tested.

"CLOVERS"

RED CLOVER

Of all the legumes red clover may well be considered as the most valuable for soil-improvement purposes, and although Plateau soils may not be naturally adapted to this crop the aim of every farmer should be to get his soil into the proper condition for its production. In the case of freshly cleared land, liming and phosphating are the main requirements. For old land, at least a light dressing of manure, or the turning under for one or more seasons beforehand of such green-manure crops as can be grown to most advantage, is essential.

The usual time of seeding is in the early spring, with some nurse crop, such as spring oats or fall-sown rye. Under favorable condi-

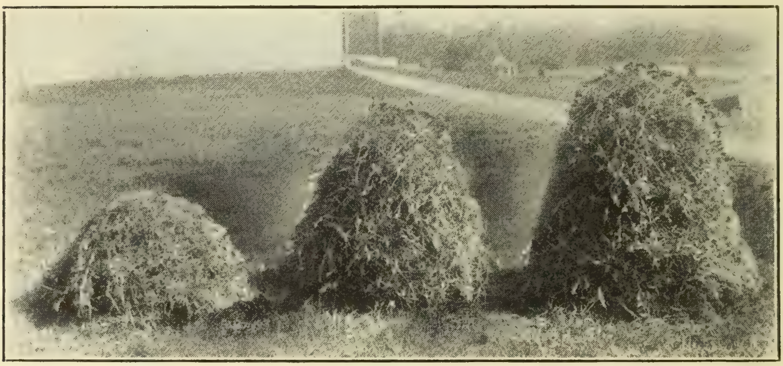
tions it may also be sown with buckwheat in July. Where the success of clover is less certain, seeding by itself in the latter part of the summer is recommended. Indeed, in this way the best crops can be obtained on almost any soil.

Inoculation of the soil for the common clovers may be of considerable importance, and should not be overlooked. Special investigation of this subject has, however, been neglected.

ALSIKE

Alsike clover is not as robust as red clover, and is, therefore, not so well suited to poor land. It has, however, done very well in our experiments, and has some advantages over red clover, especially in that it is completely resistant to the common red clover disease, which has done great damage throughout the State during the past twenty or more years. Only about two-thirds as much seed is required as for red colver.

Alsike Clover, from Experiments on Farm of J. Morrow, Creston, Cumberland County



No Fertilizer	Fertilizer	Fertilizer and Lime
0.44 ton hay per acre	1.08 ton hay per acre	1.44 ton hay per acre

WHITE CLOVER

White clover, like red and alsike, responds to liming and phosphating, and should not be overlooked as an addition to the pasture and a means of soil improvement. 1½ pound of seed per acre is suggested to be mixed with the clover and grass wherever the land is to be used for pasture purposes.

CRIMSON CLOVER

Crimson clover is a valuable green-manure crop, but only rather fertile soils are adapted to it. To get best results it should be sown by itself in midsummer, but it may be sown with buckwheat under favorable conditions.

LESPEDEZA

Lespedeza, or Japan clover, is not a true clover, but may be included with the others for practical purposes. This plant has spread over a large part of the Plateau and should be welcomed both as an addition to the pasture and a not insignificant means of soil improvement. Although found growing almost everywhere, it responds well to liming and phosphating, as was demonstrated at the West Tennessee Station. Under some conditions it may even be worth while to sow the seed. This may be done the middle of April. About 25 pounds per acre is required for a full stand the first year. Ten pounds, however, will be sufficient to give it a good start.

MELILOTUS

Melilotus, or sweet clover, like Lespedeza, is a legume but not a true clover. In the few trials made on the Plateau sweet clover failed to grow satisfactorily. The probable explanation is that this plant requires, like alfalfa, a soil well supplied with lime; also soil inoculation with the same kind of bacteria required by alfalfa, and which do not appear to be naturally present in these soils. It is probable that with attention to liming, phosphating, and inoculation, sweet clover could be grown to advantage as a green-manure crop in preparation for alfalfa. Sweet clover may be sown either in the spring, with oats, or in late summer.

COWPEAS AND SOY BEANS

Both cowpeas and soy beans are adapted to the Plateau and should be grown extensively. Very poor land which has been limed and phosphated should be planted at first in cowpeas to be pastured off or turned under for green manure and not in some non-legume, like millet or sorghum. The Whippoorwill is the standard, all-round variety, but the Clay is suggested for soil-improvement purposes, because of its more vigorous growth.

The capacity for hay production of the late-maturing varieties of soy beans is much greater than that of any variety of cowpea, but the soy bean requires more attention both in cultivation and in harvesting than the cowpea. Also soil inoculation, which never appears necessary for the cowpea, may be required for the soy bean. However, since the nodules do not seem to be entirely lacking the first year that the beans are grown, their thorough inoculation would be expected the following season if grown on the same land.

Both cowpeas and soy beans, the latter in particular, give largest yields when planted in rows and cultivated. For broadcast seeding, 1½ bushel of seed per acre is required; but for planting in rows only ½ bushel. 2½-foot rows are advised.

Only acid phosphate or a mixture of acid phosphate and muriate of potash is advised as a fertilizer.

For further information in regard to varieties of soy beans, methods of curing, etc., Bulletin 82 of this Station may be consulted.

CANADIAN FIELD PEAS AND SPRING OATS

Canadian field peas and spring oats can be grown successfully. The peas add materially to the feeding value of the hay, as do cowpeas in the common mixture of cowpeas and millet. The Canadian peas are closely related to the common smooth varieties of garden peas, and, like them, should be sown as early in the spring as possible. Both the altitude of the Plateau and the sandy nature of the soil are favorable to Canadian peas, and the mixture with oats is recommended for trial. A fair seeding per acre is 2 bushels of oats and 1 bushel of peas. In the cooperative trials there has been much evidence that soil inoculation is necessary in order to get the best results. 300 pounds of a garden soil where garden peas show nodules on the roots is sufficient for an acre, and may be either drilled in or sown broadcast and harrowed into the soil.

PEANUTS

The season is rather short for peanuts to reach full maturity, so that they can hardly be advocated except for the home garden, for which use the Spanish variety is recommended.

THE SMALL GRAINS

Wheat, as well as rye and oats, may be grown on the Plateau, but the soils are not naturally well adapted to it. They are both too poor in plant food and too light in texture. For the latter reason they heave greatly in freezing and thawing, so that fall-sown crops of all kinds either must be planted extra early or the soil be above the average in fertility; otherwise they stand a good chance of being frozen out. However, by increasing the fertility of the soil there is nothing to prevent excellent crops being obtained of all the small grains, including winter barley, which requires a richer soil than any of the others. Winter barley should be sown early in September. Wheat and rye should be sown the latter half of September. On account of the uncertainty of winter oats, only spring oats are advised. They should be sown as early in the spring as the season will allow.

In regard to fertilizers, the same suggestions as made for corn may be followed.

GRASSES

The newly cleared lands of the Plateau are rather easily set in grass, and advantage should be taken of this opportunity before the continued growing of corn, millet, etc., seriously impoverishes the

soil. Lime and phosphate are very important from the outset. Grass seed is frequently wasted by being sown on land that is too poor for any of the cultivated grasses, and emphasis is placed on the necessity of first improving such land by the use of manure or by the growing of rye, cowpeas, etc., for pasture or green-manure purposes, in addition to liming and the judicious use of phosphate. The physical make-up of these soils, the abundant rainfall, and the long growing season are all favorable, and the culture of grass is urged in connection with that of clover as an important means of maintaining fertility.

Red-top is probably the best all-round grass for both hay and pasture. With the aid of manure, lime, etc., Timothy, orchard grass, and tall oat can be grown to advantage, and under such a condition either red or alsike clover should be sown with the grass. As heavy a seeding of the clover—12 pounds of red or 8 pounds of alsike per acre—is recommended as though no grass seed were sown.

Early spring seeding, with a nurse crop of either spring oats or fall-sown rye, is the usually successful procedure, but late summer seeding of both clover and grass without a nurse crop has done well. Sometimes, however, under favorable conditions they may be sown with buckwheat, or even with cowpeas and sorghum. A mixture of tall oat grass and red clover may be sown to special advantage in late summer. They mature together, and in the Station trials have outyielded anything else. Like orchard grass, tall oat must be liberally seeded, say not less than 3 bushels (33 pounds) per acre; but if found to be a desirable grass, the seed can be easily saved at home.

Bermuda grass is not advised for this section. Kentucky blue grass may be grown under specially favorable conditions, but otherwise is not recommended.

Some successful hay raisers have depended almost entirely on rather heavy applications of manure—20 to 25 tons per acre—and the suggestion is offered that by making the soil conditions favorable to the getting of clover along with the grass, 400 pounds of acid phosphate, and 50 pounds of muriate of potash per acre would probably take the place of one-half of the manure.

Nitrate of soda may be profitable on grass, especially if a fertilizer be desired to forward a late seeding or to thicken a stand. 80 to 120 pounds per acre, to be applied early in the season, is a moderate application.

BUCKWHEAT

Buckwheat may be raised to some advantage, especially on newly cleared lands, for which only acid phosphate, at the rate of 200 to 300 pounds per acre is advised as a fertilizer. In the case of an old and rather poor soil 225 pounds per acre of Formula 2, as advised for corn, may be used.

MILLET FOR HAY

German millet, which is sown either alone or, better, with cowpeas for hay, responds well to rather heavy fertilization. Table VIII gives the average results obtained from five complete series of experiments, two conducted in different seasons on one farm, and each of the other three on different farms. The soils were poor and of similar needs to those of the Plateau, except that they were more deficient in potash.

According to these and other trials on old land, 300 pounds of acid phosphate and from 80 to 160 pounds of nitrate of soda may be used per acre with fair assurance of profit. Also a small amount of muriate of potash may be used along with the acid phosphate, the two being mixed and well worked into the ground before seeding. The nitrate is advised to be applied broadcast as a top-dressing soon after the plants come up. In the case of recently cleared land only acid phosphate is advised. Also it should be noted that in a mixture of millet and peas the phosphate and potash will encourage the growth of cowpeas in particular, but that the nitrate increases the growth of the millet much more markedly than that of the peas.

SORGHUM

The saccharine, or sweet, sorghums, are well adapted to Plateau conditions, and may be used either for forage or for syrup. The Red Top variety is advised for forage purposes, but the juice is too dark to make the best syrup. Tennessee-grown seed has proven to be superior to Western-grown seed. For syrup making the Amber variety is about as good as any. Late varieties, such as Gooseneck and Honey, which have done extra well at the Knoxville Station, are too late for the Plateau and have not proven desirable when tried there.

Sorghum may be planted either in rows and cultivated like corn or sown broadcast like millet. In either case cowpeas may be planted to advantage. For planting in rows, 6 to 8 pounds of seed are used for forage and about 4 pounds for syrup. A good mixture for broadcast seeding is 1¼ bushel of peas and ¾ bushel of sorghum. If sown in rows, ½ bushel of peas is ample.

The same kind of fertilizers recommended for corn may be used for sorghum.

The most serious trouble with sorghum sown broadcast is the difficulty of curing; and for this reason millet is often preferred, especially on fertile land. When planted in rows sorghum may be put into the silo with the best of results; otherwise it is cut and shocked and will make excellent feed up to about New Year's. The planting in rows is advised for soil of good fertility, while broadcast seeding is adapted to the poor land where the sorghum does not grow too rank.

TABLE VIII—*Fertilizer experiments with millet—average of five complete sets conducted on four different farms*

Series	Phosphate and potash per acre	Application of nitrate of soda and yield of hay per acre						
		No nitrate	40 lbs. nitrate	80 lbs. nitrate	160 lbs. nitrate	240 lbs. nitrate	320 lbs. nitrate	Series average
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	None	1622	2367	2622	3164	3429	3281	2748
2	300 lbs. acid phosphate......	2454	2782	3216	3820	4587	4357	3536
3	300 lbs. acid phosphate.. / 100 lbs. muriate of potash	2942	3240	3839	3655	4428	4671	3796
4	150 lbs. acid phosphate.. / 100 lbs. muriate of potash	2450	2754	3354	3566	4111	4365	3433
5	600 lbs. acid phosphate.. / 100 lbs. muriate of potash	1923	2980	3548	4263	4268	5159	3690
	Average of series 2, 3, 4 & 5	2278	2825	3489	3826	4349	4638	....

CROP ROTATIONS

LIST OF ROTATIONS

1. GENERAL FARMING—FIVE-YEAR ROTATION

1st year—Corn, followed by winter cover crop of rye for pasture and green manure.

2d year—Cowpeas or soy beans.

3d year—Rye or other small grain.

4th year—Clover and grass.

5th year—Clover and grass.

Note—Potatoes could be introduced the 5th year after clover instead of clover and grass.

2. GENERAL FARMING—FOUR-YEAR ROTATION

1st year—Corn—rye cover crop.

2d year—Sorghum and peas sown broadcast.

3d year—Clover and grass.

4th year—Clover and grass.

3. POTATO GROWER'S FOUR-YEAR ROTATION

1st year—Potatoes, followed by cowpeas and millet for hay.

Note—The hay crop is sown at last working of the potatoes and is harvested before the potatoes are dug.

2d year—Spring oats and Canadian field peas, followed by buckwheat, with which clover and grass are seeded.

3d year—Clover and grass.

4th year—Clover and grass.

This is a rotation practiced by Mr. O. H. Overdell on recently cleared land near Crossville.

4. POTATO GROWER'S THREE-YEAR ROTATION

1st year—Cowpeas, hogged off and followed by rye cover crop for pasture.

2d year—Potatoes, followed by rye cover crop for pasture.

3d year—Corn, with cowpeas and rye sown at last cultivation.

GUIDE IN THE ESTABLISHMENT OF A ROTATION

The writer has prepared Table IX with the view of furnishing a practical guide during the establishment of the five-year general farming rotation. The spring of the year 1914 is taken as the commencement of the project and it is assumed that the land is in an ordinary state of fertility. According to this plan the rotation will not be in full operation until 1916; at least two years being required to accomplish this result.

TABLE IX—*Five-year crop rotation (No. 1), showing crops, amount per acre of fertilizers, etc., suggested for each field during the establishment of the rotation—based on experiments conducted on Cumberland Plateau soils—all operations assumed to begin in spring of* 1914

FIELD 1	FIELD 2	FIELD 3	FIELD 4	FIELD 5
1914 — Corn—followed by a winter cover crop of rye. Acid phosphate 200 lbs., muriate of potash 10 lbs., and cotton-seed meal 100 lbs.	1914 — Cowpeas. Acid phosphate 300 lbs., muriate of potash 20 lbs.	1914—Soy beans. Acid phosphate 300 lbs., muriate of potash 20 lbs.	1914 — Spring oats. Acid phosphate 200 lbs., muriate of potash 10 lbs., nitrate of soda 80 lbs.	1914—Spring oats. Acid phosphate 200 lbs., muriate of potash 10 lbs., nitrate of soda 80 lbs.
1915—Soy beans. Acid phosphate 300 lbs., muriate of potash 20 lbs.	1915 — Rye. Ground limestone 2 tons, acid phosphate 200 lbs., manure 6-10 tons.	1915 — Corn—followed by a winter cover crop of rye. Acid phosphate 200 lbs., muriate of potash 10 lbs., cotton-seed meal 100 lbs.	1915 — Red clover — sown in Aug., 1914. Ground limestone 2 tons, acid phosphate 300 lbs., muriate of potash 25 lbs.	1915—Clover and grass (sown Aug., 1914—hay).
1916 — Rye. Ground limestone 2 tons, acid phosphate 200 lbs., manure 6-10 tons.	1916—Clover and grass (hay).	1916—Soy beans. Acid phosphate 300 lbs., muriate of potash 20 lbs.	1916 — Corn—followed by winter cover crop of rye. Acid phosphate 200 lbs.	1916—Clover and grass (chiefly for pasture).
1917—Clover and grass (hay).	1917—Clover and grass (chiefly for pasture).	1917 — Rye. Ground limestone 2 tons, acid phosphate 200 lbs., manure 6-10 tons.	1917—Soy beans. Acid phosphate 300 lbs., muriate of potash 20 lbs.	1917 — Corn—followed by winter cover crop of rye. Acid phosphate 200 lbs.
1918—Clover and grass (chiefly for pasture).	1918— Corn — followed by a winter cover crop of rye. Acid phosphate 200 lbs.	1918—Clover and grass (hay).	1918—Rye. Acid phosphate 200 lbs., manure 6-10 tons.	1918—Soy beans. Acid phosphate 300 lbs., muriate of potash 20 lbs.

It may be noted that after the establishment of the rotation—1916 and later—a change is made in the commercial fertilizers, both for corn and for the small-grain crop. This change consists in the omission of both the cotton-seed meal and the muriate of potash. In the case of the rye, the manure would much more than replace these two ingredients and the residues from the clover and grass would be expected to furnish an appreciable supply of nitrogen for the corn which follows. Also in case of freshly cleared land neither meal or potash salt is advised from the outset.

NOTES ON TABLE IX

1. The liming may be done sooner than directed in the table. In fact, although especially beneficial to clover, liming is apt to increase the yield of any of the crops to an appreciable extent. According to our experimental evidence, two tons of ground limestone will be ample for at least five years, and possibly for twice that length of time.

2. The acid phosphate and muriate of potash should always be applied before planting the crop for which they are especially intended, and give best results when applied in the row for crops planted in rows. For broadcast-sown crops these materials may be applied broadcast before the land is turned, or may either be drilled in afterward or scattered broadcast and well harrowed into the soil.

3. As a cover crop after corn, rye is especially advised for the poorer soils. Under favorable conditions, either crimson clover or hairy vetch may be used. Crimson clover is an ideal crop for this purpose in some respects, but requires a rather fertile soil in order to thrive. Even then, when sown in corn at the last working, it is apt to be killed before winter by dry, hot weather. Rye would help to hold the crimson clover from freezing out during the winter, and the mixture may be sown considerably later than crimson clover alone, any time from the middle of August to the middle of September being favorable, provided the soil moisture supply is good. Vetch sown the latter part of September is apt to go through the winter. Like crimson clover it may be sown with rye.

The cover crop should be turned under at a rather early stage of growth—in the case of rye not later than when in boot; but for crimson clover and vetch when in early bloom. Attention is called to the fact that vetch makes only a small growth during the fall, winter, and early spring, and is a vigorous grower only after warm weather comes in the spring; so that to get the most good out of this crop for green-manure purposes it must remain on the land later by several weeks than either of the others, or until about the first of June. This would not, however, be a serious objection, as either cowpeas or soy beans can be planted to advantage after this date.

4. The manure is well applied for the oat crop after the land has been turned, and is then disked into the soil. Applied in this way it is very favorable to the getting of a stand of clover and grass. If the land be new a stand of clover and grass is easily gotten. Then the manure may well be applied for the corn, which offers the greatest possible increase in yield of grain.

In the absence of manure, an extra application of both phosphate and potash is advised in the preparation for clover and grass.

5. Red clover is preferred, but alsike may be used, and a mixture of the two is sometimes advisable.

In case of a failure of clover, in the spring following the seeding an application of 100 pounds per acre of nitrate of soda may be made to advantage for the grass, and should be applied as soon as the spring growth begins, or about the middle of March.

6. The Plateau has a great advantage over most parts of the State in that there is a large amount of free range. The cattle carried over during the winter should be handled so as to save all the manure possible. Cotton-seed meal has been recommended as a fertilizer ingredient, but the best way to use it is as a feed for cattle. No other feed is equal to it either in richness or in returns for the money invested. At least one pound per head per day should be fed. and this small quantity will, without corn or other grain, but with only the common rough feed of the farm, winter stock nicely, and the cost of the meal should be gotten back in the increased value of the manure.

NATURAL MEADOWS

Small areas of poorly drained land, known as "natural meadows," are occasionally found on the Plateau. As far as the writer's observation goes, the soils of these meadows are dark colored and very rich in nitrogen and humus. Field experiments conducted on a soil of this character near Crossville showed it to be very much in need of both lime and phosphoric acid, and somewhat in need of potash. With proper drainage and the application of the minerals needed, little difficulty was found in getting excellent yields of the common farm crops, such as corn, sorghum, Timothy, and other grasses. Without liming, soy beans did better than anything else. With proper handling, garden crops could probably be grown to advantage.

Burnt lime at not less than two tons per acre is recommended. In order to get the lime well mixed throughout the soil, one-half may be applied before and one-half after plowing. At least 300 pounds of acid phosphate and 50 pounds of muriate of potash per acre is recommended.

SOY-BEAN HAY GROWN ON "NATURAL MEADOW"

A rich-looking but sour soil, on which most crops fail

BULLETIN

OF THE

AGRICULTURAL EXPERIMENT STATION

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UNLIMED LIMED

WHEAT—FROM EXPERIMENTS ON THE BARRENS TYPE OF SOIL

NUMBER 102 JANUARY, 1914

THE RATIONAL IMPROVEMENT OF HIGHLAND RIM SOILS

CONCLUSIONS FROM SIX YEARS OF FIELD EXPERIMENTS WITH VARIOUS FARM CROPS

BY

CHARLES A. MOOERS

KNOXVILLE, TENNESSEE

THE RATIONAL IMPROVEMENT OF HIGHLAND RIM SOILS

Conclusions from Six Years of Field Experiments with Various Farm Crops

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PRINCIPLES OF SOIL FERTILITY WITH SPECIAL REFERENCE TO THE HIGHLAND RIM

THE PLANT-FOOD ELEMENTS

Plants need food of different kinds, very much as do animals. That is, a plant will starve if deprived of any one of several substances in the soil, just as a man will starve if he tries to live on fat meat alone, or on starch alone, or on sugar alone, or, for that matter, on all three of these articles of food, because they lack the element that makes blood and lean meat and which is found in eggs, milk, beans, and the like. To state the case another way, a person to be well fed, must get not only food enough to satisfy his hunger, but also food that contains in proper amount the elements needed to renew all parts of the body. In like manner, plants, to be well nourished, require an abundance of each of a number of elements.

The elements necessary

The elements found in the soil which are necessary to plants are nitrogen, phosphorus, calcium, potassium, magnesium, sulphur, and iron. Those that come wholly from air and water are carbon, hydrogen, and oxygen. The latter group makes up the bulk of the dry substance of plants, or 90 to 99 parts out of 100. The element nitrogen can be given an intermediate place between the two groups, because the original source of the soil nitrogen is the air. Also certain kinds of plants, the legumes, are able to utilize atmospheric nitrogen, though this is done indirectly, through the nodule-forming bacteria found in their roots.

To the farmer the discovery of the elements that plants must have meant much, for as long as they were unknown there was no way to tell exactly what could be used to help make poor land rich. Since this knowledge was obtained the world has been searched for minerals and refuse that supply these elements; soils have been analyzed to find out how much of each they contain; and it is now possible to take almost any soil and make it fertile.

The four elements of most importance

Of the seven soil elements mentioned, only four have been found to be especially important in practical farming. That is, they are the only ones which are apt to be deficient in the soil, and which generally make the difference between a rich and a poor soil, so far as plant food is concerned. These four elements are nitrogen, phosphorus, calcium, and potassium. The last three are sometimes called the "minerals" and are generally referred to under the names of "phosphoric acid," "lime," and "potash."

Main object of bulletin

One of the main objects of this bulletin is to show the special plant-food needs of the Highland Rim soils, what fertilizers to buy, and, as far as possible, how much to use on different crops in order to get the best practical results.

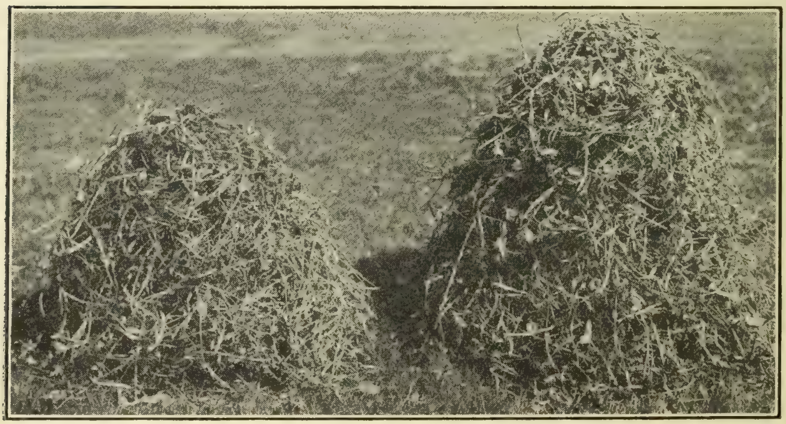
THE MINERALS

Chemical analysis tells much about a soil's supply of plant food, and if the evidence furnished by the analysis is supported by the results of field trials there can be little doubt as to the correctness of the conclusions. In the case of the gray soils of the Barrens type we have both kinds of evidence to prove that they are naturally very poor in two important mineral substances, phosphoric acid and lime, and that they are not well supplied with a third one, potash. According to the chemical analyses made at this Station, an average acre of Barrens soil to the depth of one foot contains only 1500 pounds of phosphoric acid, 3100 pounds of lime, and 5300 pounds of potash that can be dissolved out by the aid of strong, hot hydrochloric acid, as compared with 8000 pounds of phosphoric acid, 11000 pounds of lime, and 13600 pounds of potash in the rich Central Basin soil. The red-colored limestone soils of the Rim are appreciably better supplied with these elements than the gray soils, a foot-acre containing, by analysis, 2500 pounds of phosphoric acid, 5600 pounds of lime, and 9600 pounds of potash. The results of field experiments conducted in several different counties have demonstrated repeatedly that phosphoric acid is greatly needed by all the Rim soils, that liming is nearly always profitable, and that potash is often needed by the gray soils. In fact, in the case of the latter soils the need of all these substances is so great that there is no occasion for surprise that in the past many farmers have become discouraged and failed in the attempt to get satisfactory crops from such a soil Fortunately, these substances are easily obtained, and can be profitably used from the outset. Also the writer will add that the soils of the greater portion of the eastern United States are deficient in these same elements, and that little more will be found to be required by the Plateau soils than should be used elsewhere outside of a few favored localities.

COWPEA HAY—FROM EXPERIMENTS ON HIGHLAND RIM SOIL

NO FERTILIZER AND NO LIME
0.46 ton per acre

PHOSPHATE AND POTASH
1.22 ton per acre



LIME BUT NO FERTILIZER
0.80 ton per acre

PHOSPHATE, POTASH AND LIME
1.66 ton per acre

HOW MUCH AND WHAT KIND OF LIME TO USE

Ground limestone, fresh burnt lime, air-slaked lime, and wood ashes may be used for liming the land. Any one of them will "sweeten" the soil; and the Rim soils are often "sour," a condition that is unfavorable to most farm crops. A reasonable application of ground limestone is 2 tons per acre; and if it be evenly distributed this amount will probably be ample for 5, or perhaps 10, years. One ton of burnt lime is equal to

2 tons of the ground limestone, and may be used to advantage where the hauling is an important item. About 1 1-3 ton of air-slaked lime is equal to 1 ton when fresh-burnt, and about 3 tons of wood ashes are required to equal 2 tons of the ground limestone. Any of these materials can be advantageously applied for almost any crop except cotton, peanuts and possibly tobacco. The crops most benefited are the legumes, such as clovers, cowpeas, etc., but according to our field experiments corn, sorghum, millet, oats, and the like are nearly always helped to a marked extent, so that the expense of liming is often more than met the first year by the increased yields.

Why has liming been neglected? The question may now arise, If lime is highly beneficial to Rim soils, why has it not been extensively used? There are, doubtless, several reasons, such as the expense and labor of hauling and applying, but in particular a lack of knowledge in regard to its true value. The fact must be remembered that in addition to making "sour" land "sweet" lime adds only one element of plant food to the soil, and that it does not take the place of phosphoric acid, or potash, or nitrogen. The writer has little doubt that if lime were the only necessity it would have been extensively used long ago, but the fact that other things were needed complicated the matter and obscured its true value. Therefore, lime the land, but do not expect it to take entirely the place of phosphate, of manure, of soil-improving crops, or any good method of soil improvement. For further details and experimental data of different kinds, reference may be had to Bulletin 97 of this Station, "Liming for Tennessee Soils."

PHOSPHATES

Phosphoric acid is the valuable constituent of a number of commercial materials which are known as phosphates. Some kind of phosphate is a necessity in order to lay a firm foundation for a fertile and durable Rim soil; and acid phosphate is now advised as the most profitable for general use. Either Thomas slag phosphate or bone meal might be used, but they are too expensive. Raw phosphate rock is recommended by some, but, according to numerous experiments by the Station, its effect is uncertain and, if the land be limed, acid phosphate is apt to surpass it in profitableness. Unlike lime, which need be applied only once in several years, acid phosphate should be used in small quantity and applied for almost every crop. Two to three hundred pounds per acre is a practical amount for a common farm crop, such as corn, sorghum, millet, cowpeas, etc., and will more than replace the phosphoric acid which the crop removes.

Composition and grades of acid phosphate

Since acid phosphate is the basis material of the commercial fertilizer mixtures, its composition and properties should be understood by every farmer. Briefly stated, acid phosphate is made by mixing about equal parts by weight of ground phosphate rock and sulphuric acid. The acid unites with the lime of the rock phosphate and forms the sulphate of lime, or land plaster, which makes up about one-half of the acid phosphate. In addition, the phosphoric acid is changed from insoluble to soluble forms, so that plants can readily make use of it. Fertilizer dealers generally handle two grades of acid phosphate. One is guaranteed to contain 16 per cent of available phosphoric acid, and the other is of lower grade, guaranteed to contain 14 per cent of available phosphoric acid. The "high-grade," with 16 per cent guarantee, is nearly always the most economical to buy. In fact, the 14 per cent goods is apt to be made, in response to a demand for a cheap fertilizer, by mixing sand, soil, or some such material, with a high-grade goods to reduce it to a low-grade. Any such reduction costs something to make, and the freight on the material added must be paid, so that for these, as well as other reasons that may be thought of, the really dear and least profitable kind is the low-grade phosphate.

Some properties of acid phosphate

If kept under cover acid phosphate can be held over for any length of time, as it does not lose strength on standing. It should not be mixed with either lime or ashes, but even then its value is by no means destroyed. It is not lost from the soil by leaching, but in the course of a little time combines with lime, iron, or other bases in the soil, which reduce the readiness with which plants can make use of it, and hence one reason for the advice to make a light dressing to suit each crop. Wherever needed the effect of an application of acid phosphate is especially noticeable in the increased production of grain and fruit, though an increase of stem and leaf growth is also marked. Only a relatively small quantity of phosphoric acid is needed even by a large crop, but where a great deficiency exists, such as is the case with the Barrens soil in particular, successful farming will be almost impossible until the deficiency is remedied.

Not enough manure

At this point some one is sure to think of a vegetable garden or other piece of land which was made highly productive by the application of manure and where neither commercial phosphate nor lime had ever been used. Manure is a complete fertilizer, containing lime, phosphoric acid, potash, and nitrogen. It is also an alkaline substance, and tends, therefore, to "sweeten" a soil. The great value of manure is unquestioned. If every farmer had all he was willing to haul, say, four or five miles, the soil fertility prob-

lem would be solved; but unfortunately nothing of the kind is the case, either here or anywhere else, except in the neighborhood of some town or city. Furthermore, if the manure could be gotten, a good liming of the land and an application of phosphate would be profitable at the outset of the soil upbuilding, for the manure would give better returns and clover could be grown at once. The writer recalls a very successful farmer who years ago bought some poor Barrens land and brought it up to a high state of productiveness in the course of his lifetime by buying corn from his neighbors and feeding it, along with whatever else he could raise, to cattle. He considered the manure as about the chief profit, and thereby succeeded in enriching his land. In this case the necessary phosphoric acid was obtained in the corn which grew on other lands, which were therefore impoverished. All the manure is needed that can be gotten, but to get the crops that can be fed to make the manure both lime and phosphate are very important.

POTASH

Potash is little needed by the red-colored soils, so that if the major part of the crops grown be fed on the farm and the manure returned to the land, little attention need be given to this element. The Barrens soils, however, are at best only moderately well supplied, and if large crops, by the aid of liming, phosphating, and good methods of culture, be grown, and especially if crops like Irish potatoes be raised for shipment, then potash salts should be used in moderate quantity along with acid phosphate.

Muriate of potash

The cheapest of the commercial salts is the muriate of potash, which retails at nearly 3 cents per pound. It contains about 50 pounds of potash to the 100, so that potash is one of the cheap elements which can be profitably supplied whenever needed.

Wood ashes

Wood ashes contain about 5 pounds of potash to the 100, but if kept dry and unleached may contain twice this amount. Of course, in addition they contain a large amount of lime—to which the writer would attribute their chief value—some phosphoric acid, and, in fact, all of the mineral elements of plant food.

NITROGEN

As a rule the most marked difference between rich and poor land or between "new" and "old" land lies in the content of nitrogen and humus, which are abundant in the rich soil but deficient in the poor soil.

The high cost of nitrogen

Nitrogen is by far the most expensive to buy of the plant food elements. A pound of available phosphoric acid costs at the present time about 4¼ cents; a pound of potash costs nearly 6 cents; but a pound of nitrogen costs in the neighborhood of 20 cents. Moreover, plants require two or three times as much nitrogen as they do of phosphoric acid. For example, the nitrogen needed in the production of a bushel of corn would cost about 33½ cents; while the phosphoric acid would cost only 2½ cents and the potash 7½ cents. This high cost of nitrogen prohibits the use of more than a small amount for field crops and limits the amount that can be used profitably on even high-priced garden crops. It is this high cost of nitrogen that prevents the so-called "complete fertilizer" from being well balanced and containing its due proportion of nitrogen. In fact, 100 pounds of the average complete fertilizer, as commonly sold on the market, contains enough phosphoric acid for 18 bushels of corn, but only enough nitrogen for one bushel. With these facts before us, and also in view of the poverty in nitrogen of nearly all long-cultivated soils, not only on the Rim but everywhere in the Eastern States, it is evident that the problem of really building up the soil in this element must be solved in some way other than by buying it in commercial fertilizer form. To understand that fertilizers in and of themselves must fail to keep up soil fertility, because they do not furnish enough nitrogen, is very important and explains why they have so often fallen into disrepute.

Nitrogenous materials

There are a number of nitrogenous materials which are much used for fertilizer purposes, such as ammonium sulphate, dried blood, and tankage, but the two that are at this time the most easily obtained and are in other respects best adapted to general use are nitrate of soda and cotton-seed meal. Nitrate of soda contains 15 pounds and "prime" cotton-seed meal about 6¼ pounds of nitrogen per 100. For Rim soils neither is advised to be used alone, but only in connection with an application of acid phosphate.

Legumes as a source of nitrogen

Fortunately there is a family of plants that is able to get nitrogen from the air through the aid of bacteria which live in their roots. This family is known as legumes. Those of most importance are as follows: Red clover, alsike clover, white clover, crimson clover, Japan clover, alfalfa, sweet clover, cowpeas, soy beans, garden beans and peas, and vetches.

Complete fertilizer for legumes

A complete fertilizer for these crops need not contain nitrogen, hence, the usual recommendation is, after the land has been limed, to use a mixture of only acid phosphate and muriate of potash. For Rim soils the following is a moderate application for an acre of land:

200 lbs. high-grade acid phosphate
20 lbs. muriate of potash

The two ingredients should be well mixed by being shoveled together so that both may be applied at the same time.

SOIL INOCULATION

On the roots of all kinds of legumes are normally found small growths resembling warts, which are called "nodules." These nodules are produced by exceedingly small forms of plant life, the nodule-forming bacteria, which can be seen only by the aid of a powerful microscope. These bacteria take plant food of the various kinds needed from the root sap of the plants in which they live and in turn they supply the plant with more or less nitrogen, which they have the power to get from the air. If a legume be grown in a soil which does not contain these bacteria it can make use only of the soil supply of nitrogen, like other plants, such as corn or wheat. Clover, for instance, can enrich a soil in nitrogen only when the proper bacteria are present because the latter are the true nitrogen gatherers from the inexhaustible supply of the air. It has been found that widely different kinds of legumes require different bacteria. For example, cowpeas may thrive on a certain soil, the nodules proving that the right kind of bacteria are present, but alfalfa sown on the same soil may produce only yellow looking and unhealthy plants and no nodules, even though the soil be limed and well fertilized. In such a case the proper bacteria must be supplied before alfalfa can be grown successfully. This is usually done by scattering 200 or 300 pounds of earth per acre, taken from some field where alfalfa was grown successfully and was well inoculated. Also, inoculation usually follows the repeated seeding of the legume desired, and for this reason a small amount of alfalfa or of sweet clover seed is sometimes advised to be sown with clover and grass.

Some precautions

In this connection there are a few precautions which should be mentioned. First, it is not worth while to inoculate soil in great need of lime and phosphate until these substances have been supplied. Second, direct rays of the sun can kill the germs, so that the best results are obtained if the inoculating soil be either drilled into the ground or scattered broadcast on a cloudy day and then harrowed in. Third, undesirable weed seeds may be brought to the land along with the de-

sirable bacteria. It may also be mentioned that after a soil has once become thoroughly inoculated a second inoculation is seldom if ever needed.

Crops that may need inoculation

The Barrens soils have proven rather poorly supplied with bacteria, and if any of the following crops be grown, soil inoculation may be required at first in order to get the best results: Vetch, crimson clover, soy beans, sweet clover, and alfalfa. For the last two crops in particular inoculation should always precede the first seeding.

AZOTOBACTER

There is another and very important group of bacteria, which appear to be nearly everywhere, and which supply the soil with nitrogen from the air. They are called azotobacter. Unlike the nodule-forming kinds, azotobacter are independent of the higher forms of living plant life. The conditions favorable to their best development are abundant supplies of lime, phosphoric acid, air, and some kind of organic matter, such as would be furnished by manure, rye or other green crop turned under, the carbon of which they use as a source of energy. Meadow land conditions seem to be favorable to them, for meadows are found to gain in nitrogen even when no legumes are present.

HUMUS

One of the soil constituents which are well known to decrease under usual cultivation is humus, as the dark-colored organic substances which result from the decay of vegetable matter, etc., are called. The value of vegetable matter in the soil is not apt to be overestimated, for the humus produced from it increases the water-holding capacity of the soil and improves the texture, so that the soil is less inclined to bake and be cloddy. Also its importance in connection with different kinds of necessary bacteria is very great.

GREEN-MANURE FARMING

The growing of a legume, to be turned under and followed with a money crop, is known as green-manure farming and has been practiced very successfully both in some parts of Europe and in this country. New Jersey farmers have grown crimson clover to be turned under and followed with either potatoes or corn, not only getting large crops, but also building up the soil at the same time. Crimson clover is being grown to advantage in various parts of Tennessee and should receive special attention as a means of soil improvement. Many soils, however, are too poor in vegetable matter for any of the clovers, in which case cowpeas and rye may be used as green-manure crops at the outset.

CROP ROTATION

A proper rotation, or change of crops, has much to do with soil fertility. In the most prosperous and longest organized farm communities definite crop rotations are followed year after year with little variation. The kind of crops grown must of course be suitable to the climate, the soil, and the market conditions, but there are certain essentials to be kept in mind.

1. Leguminous crops are necessary to bring nitrogen from the air. For this purpose cowpeas are the most easily gown, but in order to be of most benefit to the soil the crop must be either pastured off or turned under. Soy beans resemble cowpeas as soil improvers, but neither is equal to either crimson or red clover, with which alsike may be included. The clovers should be especially sought, for once the conditions for their satisfactory growth have been gotten, the solution of the soil fertility problem is not difficult.

2. There should be one or more cultivated crops so that weeds may be kept in check or eradicated. Good crops for this purpose are Irish potatoes, cowpeas or soy beans planted in rows, sorghum, and corn.

3. To put vegetable matter into the soil and increase its water-holding capacity, a grass crop is very important.

Generally speaking a long rotation, covering a period of five or more years, is better than a short two-or-three-year rotation. The following is given as an example of a good, practical rotation:

1st year—Corn, followed by cover crop of rye sown at last working.

2d year—Cowpeas or soy beans.

3d year—Wheat or other small grain.

4th year—Clover and grass (chiefly clover).

5th year—Clover and grass (chiefly grass).

This means that the cultivated part of the farm is divided into five fields and that each year, as soon as the rotation is fully established there is one field in corn, one in cowpeas or soy beans, one in a small grain, one in first-year clover and grass, and one in second-year clover and grass. For a complete scheme of the crops that may be grown in order to reach this rotation, and the fetilizers, etc., suggested, see page 42.

SOME RESULTS OF FIELD EXPERIMENTS

FERTILIZERS FOR IRISH POTATOES

QUANTITY OF COMPLETE FERTILIZER

Table I gives the results obtained in nine series of experiments conducted on as many different soils of varying fertility. The fertilizer used consisted of the following mixture:

300 lbs. high-grade acid phosphate
50 " muriate of potash
400 " cotton-seed meal

The approximate cost of 750 pounds of the mixture was $9.90. In one-third of the trials this amount per acre proved more profitable than twice the quantity, and is recommended as a conservative application. 1,500 pounds per acre proved, however, to be on the average the more profitable, and would, of course, leave a larger residue for the benefit of the succeeding crop. The results were obtained in different seasons, but probably represent rather favorable conditions for this crop.

TABLE I—*Fertilizer experiments with Irish potatoes, testing two rates of application,* 750 *and* 1500 *pounds per acre, of a complete fertilizer—results of nine series, each conducted on a different farm*

Series	Yield per acre without fertilizer		Yield per acre with 750 lbs. complete fertilizer		Yield per acre with 1500 lbs. complete fertilizer	
	Total	Salable	Total	Salable	Total	Salable
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
1	61	52	104	81	136	122
2	57	36	101	80	109	92
3	37	17	96	76	108	88
4	24	4	109	54	158	91
5	32	20	142	131	191	180
6	73	63	123	110	136	121
7	54	46	164	147	198	177
8	155	139	193	180	221	205
9	110	90	167	151	228	199
Average	67	52	133	112	165	142

COTTON-SEED MEAL VERSUS NITRATE OF SODA FOR POTATOES

Table II gives the results obtained on seven different farms where experiments were made to compare the effect of nitrogen from cotton-seed meal with that from nitrate of soda for Irish potatoes. 400 pounds of the meal was assumed to contain the same amount of nitrogen as 160 pounds of the nitrate. Acid phosphate and muriate of potash were used in every case in sufficient quantity to make the nitrogen fully effective. The averages of the series show that nitrate of soda was only slightly more efficient than the cotton-seed meal, the average total yield being 145 bushels where the nitrate was used, as compared with 140 bushels where meal was used; but the average quantity of salable potatoes was the same for each. Nitrate of soda has the advantage of being somewhat cheaper than cotton-seed meal, but the disadvantages that it cannot be so generally obtained, is apt to be lumpy and need pulverizing, and is preferably applied separately from the phosphate and potash as a surface dressing.

TYPICAL RESULTS FROM EXPERIMENTS WITH POTATOES

No Fertilizer	12 Tons Manure Per Acre	12 Tons Manure and 600 Lbs. Acid Phosphate Per Acre
44 Bu. per acre	130 Bu. per acre	179 Bu. per acre

FARMYARD MANURE ALONE AND REINFORCED WITH FERTILIZERS

Farmyard manure can be used with extra good chance of profit on the Irish potato crop. According to the results of Table III, 12 tons of manure per acre gave, as the average of six series of experiments, an increase of 92 bushels of salable potatoes, or 7 2-3 bushels per ton of manure. Farmyard manure is considered to be a complete and well-balanced fertilizer for a soil that is fairly well supplied with the mineral elements, phosphoric acid and potash, but for Rim soils an additional supply of phosphoric acid in particular is needed in order to make manure most efficient. The average of five series of

Table II—*Fertilizer experiments with Irish potatoes, with special reference to a comparison between cotton-seed meal and nitrate of soda as sources of nitrogen—results of seven series, each conducted on a different farm*

Series	Yield per acre without fertilizer		Yield per acre with phosphoric acid and potash No nitrogen		Yield per acre with phosphoric acid, potash and nitrogen from cotton-seed meal		Yield per acre with phosphoric acid, potash and nitrogen from nitrate of soda		Notes
	Total	Salable	Total	Salable	Total	Salable	Total	Salable	
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	
1	24	4	(33)	(6)	82	71	105	59	400 lbs. meal vs. 160 lbs. nitrate
2	32	20	93	82	162	150	156	146	400 " " 160 "
3	81	64	150	127	164	150	157	148	600 " " 240 "
4	73	63	96	84	130	115	129	116	450 " " 180 "
5	89	79	93	83	85	74	102	89	300 " " 120 "
6	155	137	167	152	179	164	190	177	800 " " 320 "
7	110	90	(153)	(131)	181	162	173	153	400 " " 160 "
Average	81	65	112	95	140	127	145	127	480 " " 192 "

TABLE III—*Fertilizer experiments with Irish potatoes. Manure alone vs. manure reinforced with commercial fertilizers—six series conducted on six different farms*

Series	Yield per acre without fertilizer		Yield per acre with 12 tons manure		Yield per acre with 12 tons manure and 600 lbs. acid phosphate		Yield per acre with 12 tons manure, 600 lbs. acid phosphate, 100 lbs. muriate of potash, and 320 lbs. nitrate of soda		Yield per acre with 12 tons manure, 600 lbs. acid phosphate, and 320 lbs. nitrate of soda	
	Total	Salable	Total	Salable	Total	Salable	Total	Salable	Total	Salable
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
1	50	45	153	126	212	179	...	...	...	...
2	42	22	195	150	...	...	315	266	...	...
3	24	4	196	140	248	208	286	251	286	254
4	32	20	128	116	209	201	215	206	...	...
5	110	90	212	193	237	213	244	228	242	223
6	83	62	109	76	139	111	159	127	145	114
Series 1-6 averaged	57	41	166	133	...	...	...	...	...	...
Series 1, 3-6 averaged	60	44	160	130	209	182	...	...	...	...
Series 2-6 averaged	58	40	168	135	...	...	244	216	...	...
Series 3, 5, 6 averaged	72	52	172	136	208	177	230	202	224	197

experiments gives an increase of 138 bushels of salable potatoes from an application of 12 tons of manure, reinforced with 600 pounds of acid phosphate, as compared with an increase of only 86 bushels from 12 tons of manure alone. As the average of three trials, the application of 320 pounds per acre of nitrate of soda, in addition to 12 tons of manure and 600 pounds of acid phosphate, resulted in a further increase of 20 bushels of salable potatoes per acre. The results of the experiments in which 100 pounds of muriate of potash per acre were used in connection with 600 pounds of acid phosphate and 320 pounds of muriate of potash as a supplement to the manure, are not favorable to the use of the potash salt.

VARIETY TRIALS OF IRISH POTATOES

Several variety trials were made with Irish potatoes, but they were neither as extensive nor as long continued as is necessary in order to get conclusive results. According to the results obtained, Burbank and Green Mountain were the best late varieties, and Early Rose and Irish Cobbler the best medium-early. Bliss Triumph was found to be one of the lowest yielders, but its earliness is ample reason for its popularity. "Second-crop" seed of the Triumph variety are justly given first place over Northern-grown seed, but mention should be made of the fact that the continued planting of small seed is very apt to cause the variety to "run out," so that a very inferior strain is the result. On the other hand, the selection of good-sized seed potatoes from productive hills will have a strong tendency to improve the crop.

TIME OF APPLICATION OF NITRATE OF SODA

Nitrate of soda—value and properties

Nitrate of soda furnishes nitrogen in its most available form for plant-food purposes, especially for cereal crops. It is also about the cheapest commercial source of fertilizer nitrogen. These two reasons are sufficient to warrant the study on the part of every farmer of the most important principles concerning its use. Nitrate of soda is very readily soluble in water and may be lost from the soil by leaching, but this chance of loss is much less than might be supposed, as the results of Table IV show. It may be decomposed and nitrogen be lost into the air by being mixed with acid phosphate, but in practice such loss is apt to be small. Nitrate takes up moisture from the air in considerable quantity, and the mixture with acid phosphate will, if sufficient nitrate be present, soon become sticky, so that there are two reasons against mixing acid phosphate and nitrate of soda. Fertilizer manufacturers have found, however, that they could add a small amount to their mixture without bad results,

and this is not an uncommon practice. Because of the chance of loss by leaching and of the possible bad results from mixing with other fertilizer materials, nitrate of soda is usually applied by itself as a top-dressing. The generally accepted rules in regard to its use are as follows:

Rules for use of nitrate

1. If the soil be poor in either phosphoric acid or potash, nitrate should not be used until the deficiency in these mineral elements be supplied. According to numerous trials on Highland Rim soils, 300 pounds of acid phosphate and 50 pounds of muriate of potash are ample to reinforce 160 pounds of nitrate.

2. For fall-sown small grains, a very light application—say 40 pounds per acre—may be made at the time of seeding, provided the soil be poor and there be some danger of the crop's freezing out; otherwise all of the nitrate is applied as soon as spring growth starts, or sometime in March. For spring and summer crops the nitrate is applied as a top-dressing when the plants are small.

3. Nitrate should not be applied when the leaves of the plants are wet with rain or dew, as burning is apt to follow.

4. With light applications, up to, say, 200 pounds per acre, all the nitrate may be applied at one time, but with heavy applications one-half is often advised to be applied at an early stage of growth and the balance in ten days or two weeks.

EXPERIMENTAL EVIDENCE

For the reason that there is at the present time a wide difference between the recommendations of some writers in regard to the time at which nitrate should be applied, experiments were undertaken on this subject with two crops, corn and Irish potatoes. The soils used were, of course, deficient in nitrogen in each case, and phosphate and potash were applied in ample quantity to make the nitrate effective. Table IV gives the schemes followed and the results obtained as an average of several trials for each crop.

DISCUSSION OF THE RESULTS

Early application best for corn

The results with the corn point very definitely to the application of the nitrate at an early stage of growth, the gain being greatest when the plants were from 3 inches to 2 feet high. Of special interest were the results following the application made at tasseling time, for in none of the three series from which the averages were obtained did any increase in yield of grain result from this time of application, the only apparent effect being a deeper green foliage.

TABLE IV—*Experimental results relating to time of application of nitrate of soda*

Crop	Exp. No.	Amount of nitrate applied per acre	Time of application of nitrate	Yield per acre		Remarks
				Grain Bu.	Stover Ton	CORN
Corn	1	None	....	25.7	1.19	The average of three complete sets conducted on three different farms, each in a different section of the State. Phosphate and potash used on all plots alike.
	2	100 lbs.	When plants about 3 in. high	31.2	1.39	
	3	"	" " " 2 ft. "	31.4	1.32	
	4	"	" " " 3½ "	30.0	1.25	
	5	"	As soon as in tassel	24.8	1.26	
				Salable tubers Bu.	Culls Bu.	POTATOES
Irish potatoes	1	None	....	78	14	Average of four sets on four different farms, three on Cumberland Plateau and one on Highland Rim. Phosphate and potash used in ample amount to balance nitrate.
	2	320 lbs.	Mixed in row before planting	145	22	
	3	"	In one application as soon as plants came up	150	16	
	4	"	In two applications, ½ as soon as plants up and ½ about 12 days later.......	133	20	

Early application best for potatoes

The results of the experiments on Irish potatoes are of special interest, as three of the four sets were made on the fine sandy loams of the Plateau, which might be expected to suffer from leaching. In practically every one of the four sets nearly as good results as any were obtained when the nitrate was mixed with the phosphate and potash applied in the row before planting. This was rather unexpected, for the rainfall at this time of the year is heavy, so that loss of nitrate would be looked for. The results from applying one-half of the nitrate as a top-dressing when the plants were just coming up, and the balance in ten days or two weeks, were unfavorable to this method. As with the corn, the results are, therefore, decidedly in favor of an early application.

FERTILIZERS FOR CORN

PHOSPHATE AND POTASH

Corn is a very important crop, but one that is low-priced, so that the question as to the most profitable fertilizer is not always easy to answer. Fertilizer experiments covering every condition have not been possible, but considerable evidence has been obtained. With regard to phosphate, acid phosphate in moderate quantity, say 200 pounds to the acre, is recommended, and may be used by itself with as good a chance for profit as any other material or combination of materials of equal money value; it may even give greater profit, especially in the case of freshly cleared land. If a light dressing of manure can be made, then the plain acid phosphate is highly advisable as a supplement to the manure, which, as demonstrated in the potato experiments, is strengthened in its weakest point for soils like these. In a similar manner acid phosphate is recommended for a green-manure or pasture crop which is to be followed by corn, the one application in that case answering fairly well for the two crops.

The experimental results do not warrant anything more than a very light application of a potash salt, say, 10 pounds per acre of muriate of potash mixed with the acid phosphate.

CAN NITRATE OF SODA BE USED PROFITABLY FOR CORN?

We have now to consider the value of nitrogenous materials when used in combination with acid phosphate and muriate of potash. In particular, the question arises, Can nitrate of soda be used profitably for corn?

In order to answer this question field experiments have been conducted at various places in the State. In some instances the experiments have been rather extensive, embracing 25, and even 30, plots, some of which received no fertilizers, some only phosphate and potash, others

only nitrate, and a fourth set receiving phosphate, potash, and nitrate. Such a series was conducted in Warren County for each of three seasons, 1908, 1911 and 1912. In Table V are presented the fertilizer scheme and the results of the series conducted in 1912 on the farm of A. P. Titsworth, in Warren County. This series is given by itself for the reason that the results are characteristic of those obtained from nitrating under very favorable seasonal and soil conditions. According to these experiments, the cost of nitrate for each bushel of increase produced by it was 32 cents for the 40-pound application for an acre, 31 cents for the 80-pound application, 37 cents for the 160-pound, and 46 cents for the 240-pound. Under less favorable conditions the increased yield proved insufficient to pay for the nitrate, and in very unfavorable seasons no increase in grain production was obtained. Evidently there is considerable risk run. All things considered, the margin of profit appears at the present time to be too small to permit the recommendation of nitrate of soda for the corn crop, except possibly a very light application under special conditions of nitrogen deficiency.

A COMPLETE FERTILIZER FOR VERY POOR SOILS

In order to get additional data with regard to a practical formula for corn, experiments were undertaken with three different mixtures, each of which was tested at three different rates. Table VI gives the average results of six sets of these trials, which were conducted in the seasons of 1907, 1910, and 1911. Each set was conducted on a different farm, and the unfertilized plots gave yields ranging from 6.3 to 24.1 bushels per acre, the average being 15.5 bushels per acre. The experiments were made, therefore, under strictly poor-land conditions, but such as are of common occurrence.

The three formulas used were as follows:

FORMULA 1

1200 lbs. high-grade acid phosphate
100 " muriate of potash
480 " cotton-seed meal

This mixture analyzes approximately—
11 per cent available phosphoric acid
1¾ " " nitrogen
3 " " potash

FORMULA 2

1200 lbs. high-grade acid phosphate
100 " muriate of potash
720 " cotton-seed meal

This mixture analyzes approximately—
10 per cent available phosphoric acid
2½ " " nitrogen
3 " " potash

TABLE V—*Fertilizer experiments on corn, with special reference to nitrate of soda—experiments conducted on farm of A. P. Titsworth, Warren County*

Series	Phosphate and potash per acre	Application of nitrate and increased yields per acre											
		No nitrate		40 lbs. nitrate		80 lbs. nitrate		160 lbs. nitrate		240 lbs. nitrate		Average	
		Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
		Bu.	Ton	Bu.	Ton	Bu.	Ton	Bu.	Ton	Bu.	Ton	Bu.	Ton
1	No phosphate; no potash....	*	*	2.4	0.16	0.0	0.14	0.6	0.12	5.1	0.20	2.0	0.16
2	300 lbs. acid phosphate......	11.4	0.66	12.6	0.58	15.5	0.64	21.5	0.62	21.7	0.78	16.5	0.66
3	300 lbs. acid phosphate.. / 100 lbs. muriate of potash	6.4	0.50	9.9	0.62	....	....	20.6	0.78	20.8	0.86	14.4	0.69
4	150 lbs. acid phosphate.. / 100 lbs. muriate of potash	6.2	0.36	12.1	0.46	12.6	0.44	16.9	0.24	....	....	12.0	0.38
5	600 lbs. acid phosphate.. / 100 lbs. muriate of potash	8.9	0.56	13.5	0.72	19.6	0.76	25.8	0.84	26.5	0.74	18.9	0.72
	Average of series 2, 3, and 5	8.2	0.52	12.0	0.60	15.9	0.61	21.2	0.62	23.0	0.79	....	....

*Average of five unfertilized plots, 36.5 bushels grain and 1.08 ton stover per acre.

FORMULA 3

1200 lbs. high-grade acid phosphate
100 " muriate of potash
1440 " cotton-seed meal

This mixture analyzes approximately—

8 per cent available phosphoric acid
3½ " " nitrogen
2½ " " potash

OBJECTS IN VIEW

Attention is called to the fact that in the experiments the low rate for each formula—135 pounds of Formula 1, 150 pounds of Formula 2, and 200 pounds of Formula 3—contains the same quantity of acid phosphate, or about 90 pounds per acre; also each contains about 6¾ pounds of muriate of potash per acre; so that the differences are due entirely to a variation in the amount of cotton-seed meal used. In a similar manner, the medium rates of 202, 225, and 308 pounds each contained the same amounts of acid phosphate and muriate of potash; namely, 134 pounds of the former and 11 pounds of the latter per acre. In the heavy rates of 404, 450, and 617 pounds per acre the amount of acid phosphate for each was 270 pounds and of muriate of potash 22.5 pounds per acre. The experiments, therefore, resolve themselves into only two distinct objects; one to determine the proportion of cotton-seed meal which would be the most profitable to use with a given amount of the acid phosphate and muriate of potash, and the other to determine the quantity of the complete mixture which would be the most advisable to use. In all the trials the fertilizer was applied in the row and mixed with the soil by running a shovel plow through it before planting.

RESULTS OF EXPERIMENTS

The results of these experiments seem to justify the use of a complete fertilizer for corn on very poor soils like these. The largest gross profit was obtained where a medium application of 308 pounds per acre of Formula 3 was made. The second largest gross profit was obtained where the medium application of 225 pounds of Formula 2 was used. If the average gross profit of the three formulas be calculated, then Formula 3 ranks highest, with $4.32 per acre; Formula 2 ranks second, with $3.92 per acre; and Formula 1 ranks lowest, with an average profit of only $2.74 per acre. The question arises, however, Do the results justify the recommendation of Formula 3, which gave both highest yield and largest gross profits. In the writer's opinion they do not, for the reason that the margin of profit which can be attributed to the large proportion of cotton-seed meal in Formula 3 is too small to warrant the risks incurred. The moderate application of 225 pounds per acre of Formula 2 is, therefore, advised as both conservative and practicable. According to these

TABLE VI—*Trials of three different fertilizer mixtures for corn—seasons of* 1907-1912—*average of six sets—four on Highland Rim and two on Cumberland Plateau*

Fertilizer used per acre	Yield per acre		Increase over unfertilized plots		Value of increase @ 60c per bu.	Cost of fertilizer	Cost of increase per bu.	Profit per acre from fertilizer
	Grain	Stover	Grain	Stover				
	Bu.	Ton	Bu.	Ton				
135 lbs. Fomula I..........	21.0	0.98	5.5	None	$3.30	$1.51	$0.27	$1.79
202 " " "..........	23.7	1.18	8.2	0.10	4.92	2.26	.27	2.66
404 " " "..........	29.3	1.40	13.8	0.32	8.28	4.52	.33	3.76
150 " " II..........	24.7	1.28	9.2	0.20	5.52	1.72	.19	3.80
225 " " "..........	27.6	1.29	12.1	0.21	7.26	2.59	.21	4.67
459 " " "..........	29.6	1.41	14.1	0.33	8.46	5.18	.37	3.28
206 " " III..........	25.2	1.27	9.7	0.19	5.82	2.50	.26	3.32
308 " " "	30.1	1.37	14.6	0.29	8.76	3.74	.26	5.02
617 " " "	35.7	1.49	20.2	0.41	12.12	7.50	.37	4.62
No fertilizer	15.5	1.08						

experiments it raised the average yield of corn from 15.5 bushels to 27.6 bushels per acre, at a cost of only $2.59. It may be of interest to note that 225 pounds of Formula 2 contains as much phosphoric acid as is removed by the grain and stover of a 40-bushel crop, enough potash to replace that removed by 5½ bushels and nitrogen to equal that removed by only 3 bushels, the stover being included with the grain in each case.

LIMED 53.7 Bu. per acre — UNLIMED 44 Bu. per acre

CORN

VARIETIES OF CORN

In the variety experiments on corn perhaps nothing was developed in a more pronounced manner than the adaptability of certain varieties to definite soil conditions. For example, Hickory King proved itself to be a superior poor-land variety and was followed closely in this respect by Leaming and Iowa Silver Mine, both of which appear to be well suited to the Highland Rim. They are also the best early varieties of field corn discovered in the Station trials. Boone County White was found to be early, but adapted only to rich land. Varieties like the well-known Huffman, Webb's Improved W tson, and the ensilage corns, Albermarle Prolific and Cocke's Prolific, are strictly adapted to rich lands, for which they out-class Hickory King, etc. Red-cob corn is not one variety, but consists of many varieties with various lengths of season and wide adaptabilities, but agree in pos-

sessing white grains and red cobs, although usually white cobs are to be found, which shows that the types are not standardized. In general these red-cob corns were not found to equal the pure varieties, such as Hickory King, etc. According to trials at both the Knoxville and the Jackson Station, the Looney variety, a white corn with a white cob, which is grown in the vicinity of Winchester, is fully the equal of Hickory King in grain production.

For rich land

The following table, which is based on data obtained at the Experiment Station farm, at Knoxville, gives dates when the best varieties may be planted on rich land to get a succession of crops for hog pasture or the like:

Variety	Date of planting	Date of maturity
Reid's Yellow Dent	Apr. 15	Aug. 25
Hickory King	" 15	Sep. 4
Webb's Improved Watson	" 15	Sep. 10
Huffman	" 15	Sep. 19

For poor lands only Hickory King, Looney, Leaming and Iowa Silver Mine are recommended. The question as to what is meant by "rich" and what by "poor" lands naturally arises at this point. From numerous results obtained over a series of about ten years at the Experiment Station the conclusion is drawn that up to about 50 bushels per acre Hickory King is unsurpassed. On lands which produce 50 or more bushels of corn, Webb's Watson and Huffman are apt to yield better.

FERTILITY EXPERIMENTS ON A VERY POOR GRAY-COLORED SOIL OF THE HIGHLAND RIM

During the seasons of 1910, 1911 and 1912 a valuable series of fertility experiments were conducted on a very poor gray-colored silt loam on the farm of D. T. Allison, near Baxter, in Putnam County. The soil was known to be very deficient in both phosphoric acid and nitrogen, and field corn without fertilizer or other manurial treatment yielded only 8 to 15 bushels per acre. The experimental tract was divided into four sections, and the crops grown on each section, and their disposal are indicated as follows:

	1910	Corn	Hogged off
Section A	1911	Soy beans	"
	1912	Corn	For grain
	1910	Soy beans	Hogged off
Section B	1911	Corn	"
	1912	Corn	For grain
	1910	Cowpeas	Hogged off
Section C	1911	"	"
	1912	Corn	For grain
	1910	Cowpeas	Turned under
Section D	1911	"	"
	1912	Corn	For grain

Each section was divided into several plots for the purpose of getting the effects of acid phosphate and of liming under each of the four conditions of cropping. The plots of all the ranges were of course handled alike with regard to preparation, time of planting, etc. The treatment of each of three plots of every section is reported in Table VII, which gives the yield of corn obtained the third year, 1912.

DISCUSSION OF RESULTS

The experiments afford a striking demonstration of the rapidity with which even a poor soil responds to proper treatment. The results show both the marked increase in yield which may be brought about by the pasturing off of legumes, such as cowpeas and soy beans, and the great value of acid phosphate rightly used. Liming appears profitable for these crops and would probably be a necessity in order to get clover. It should be noted in this connection that in the season of 1912 corn in neighboring fields and on the same character of soil as that used in the experiments produced less than 10 bushels to the acre.

ALFALFA

Suitable soils

The dark-red soil of the Rim is, as previously stated, well suited to general farm crops. Under good management clover and grass are grown profitably, and within the last few years alfalfa has been successfully grown in different places, but particularly in the vicinity of Belvidere, Franklin County, where the writer has seen excellent fields of 30 or more acres, which had been cut from one to five years. This success has been had chiefly on farms where live stock has played an important part in the improvement of the soil and where first-class methods of management have been followed for a number of years, but is by no means limited to this condition, for excellent crops have been obtained by many farmers on relatively poor land and without the aid of farmyard manure.

Several series of cooperative experiments were conducted on both the red and the gray soils, none of which were of more than ordinary fertility. The results proved that with attention to its special requirements alfalfa could be grown with at least moderate success on either type, although the dark red soil is, as would be expected, considerably better adapted to it than the gray soils.

Liming necessary

Liming proved to be a necessity, and rather extensive experiments were made in order to determine the most rational amount. The results proved that very heavy liming was not needed. In fact, 2 tons appeared to do as well as any larger quantity. In order to be on the safe side, 3 tons per acre is recommended as ample, and, according

TABLE VII—*Experimental results with corn following pasture and green-manure crops on very poor gray-colored soil of the Highland Rim—season of 1912—experiments conducted on farm of D. T. Allison, Putnam County*

Section	Plot	Previous crops	Fertilizer per acre	Yield per acre of corn
				Bu.
A	1	Corn, 1910—pastured; Soy beans, 1911—pastured	300 lbs. acid phosphate in both 1910 and 1911.	37.7
	2	" "	2 tons ground limestone in 1910; 300 lbs. acid phosphate in both 1910 and 1911.	39.2
	3	" "	No phosphate and no lime.	29.4
B	1	Soy beans, 1910—pastured; Corn, 1911—pastured	Same as Section A, Plot 1	31.0
	2	" "	" A, " 2	36.0
	3	" "	" A, " 3	27.1
C	1	Cowpeas, 1910—pastured; Cowpeas, 1911—pastured	" A, " 1	45.9
	2	" "	" A, " 2	49.0
	3	" "	" A, " 3	26.2
D	1	Cowpeas, 1910—turned under; Cowpeas, 1911—turned under	" A, " 1	49.0
	2	" "	" A, " 2	44.1
	3	" "	" A, " 3	31.9

to trials at the Knoxville Station, would be expected to be sufficient for eight or ten years. In order to get the limestone thoroughly mixed throughout the soil, one-half may be applied before plowing and well disked into the soil, and one-half after plowing.

Phosphates important

An abundant supply of phosphate is of very great importance. In the experimental work 500 pounds of acid phosphate and 500 pounds of bone meal were used per acre as a supplement to the manure. This is heavy phosphating, but furnishes no more phosphoric acid than would be removed by four tons of alfalfa hay per annum in five years. The thor ugh mixing of the phosphate with the soil is essential to the best results. At least in the case of a heavy application one-half may well be applied and disked into the soil before plowing and the other half afterward.

Potash may be of value

Potash did not always prove necessary—perhaps due to the amount of manure used—but 100 pounds per acre of muriate of potash is advised, and may be applied along with the acid phosphate.

Manure of much value

Farmyard manure is a great help in getting a stand of alfalfa, even on rich land, and on very poor land should be considered a necessity. 12 tons per acre were found to be ample. It is well to make the application early in the season, so that weed seeds may have a chance to sprout and be killed before the alfalfa is sown. Undoubtedly the manure may be reduced in quantity or even omitted if green-manure crops, such as crimson clover, sweet clover, etc., are grown in preparation.

Inoculation necessary

At the Knoxville Station, and occasionally elsewhere, soil inoculation is not required, but in the majority of instances it is a necessity. Certainly the risk of failure is too great for inoculation to be omitted the first time that a field is sown. The most certain plan is to use, say, 300 pounds per acre of soil from an old alfalfa field where the nodules were abundant on the roots of the plants. The inoculating soil may be screened and drilled in like fertilizer to advantage, but if scattered broadcast a cloudy day should be selected and the application should be harrowed into the ground.

Late summer or early fall seeding best

The best time of seeding is the latter half of August or early in September—early enough so that the plants will go through the winter without being frozen out. Wheat or other small grain, or Irish potatoes, may precede alfalfa, but a summer crop is apt to leave the ground so dry that the necessary fall growth can not be made. The best plan, therefore, is to

tu n the land in June, or as early in July as possible, and keep well harrowed in order to destroy weeds and to provide a moist and mellow seed-bed.

Amount of seed

24 pounds of seed per acre—12 pounds sown each way—is advised unless the soil and seasonal conditions be very favorable. A heavy seeding is necessary in order both to crowd out weeds and to allow for the thinning of the stand, which always takes place, due to disease, weeds, losses by harrowing, etc.

Nurse crops and reseeding

Nothing in the way of a "nurse crop" should be used, the results of the experiments showing that the greater the "nurse crop" the less was the alfalfa. Spring seeding is justifiable, and can be recommended for one purpose only, and that is, to thicken a

MANURE ONLY MANURE, PHOSPHATE, POTASH AN. LIME

ALFALFA HAY

poor stand obtained the previo s fall. Attempts to thicken a stand two or more years old have, in our trials, always failed.

Harrowing necessary

Two weeds have proven to be especially troublesome in alfalfa culture; one is crab-grass, which flourishes only in the summer, and the other is chickweed, which is dangerous only in the winter. In either case, harrowing with a specially constructed alfalfa harrow is the remedy. Harrowing should be done after every cutting, beginning with the first one in the spring. In this way alfalfa at the Station farm has been kept free of crab-grass for the past five years.

Time of cutting Cutting is recommended as soon as the new shoots at the base of the plants are two to three inches long. In very dry weather the yellowing of the leaves may indicate that cutting is advisable even though the growth be very small.

Top-dressing In order to maintain a stand on average upland, a top-dressing of manure or fertilizer, or both, may be necessary about the third season. Eight or ten tons of manure per acre may be applied in late winter or in early spring. Preferably the manure from cattle fed on silage and cotton-seed meal should be used both because of its richness and because of its freedom from weed seeds. Six tons of manure and 200 pounds of acid phosphate per acre would also be a fair application. If fertilizer alone be used, a mixture of 300 pounds of acid phosphate and 100 pounds of muriate of potash is recommended, to be applied at the same season as advised for the manure.

"CLOVERS"

RED CLOVER

Of all the legumes red clover may well be considered as the most valuable for soil-improvement purposes, and although much of the Rim may not be naturally adapted to this crop, the aim of every farmer should be to get his soil into the proper condition for its profitable production. In the case of freshly cleared land liming and phosphating are the main requirements. For old land there must usually be given, in addition, at least a light dressing of manure, or there may be turned under for one or more seasons beforehand such green-manure crops as can be grown to most advantage. According to common farm practice, seeding is nearly always done in the early spring, with some nurse crop, such as wheat or oats, but the Station's experimental results have demonstrated that where the success of clover is rather uncertain, seeding without a nurse crop in the latter part of August or early in September is advisable. Indeed, in this way the best crops can be obtained on almost any soil. The land should be plowed early in the summer and kept well harrowed to destroy weeds and conserve the moisture supply, so that a stand can be obtained at the proper time.

ALSIKE

Alsike clover is not as robust as red clover, and is, therefore, not so well suited to poor land. It has, however, done very well in our experiments, and has some advantages over red clover, especially in that it is completely resistant to the common red clover disease, which has done great damage throughout the State during the past

twenty or more years. Only about two-thirds as much seed is required as for red clover.

WHITE CLOVER

White clover, like red and alsike, responds to liming and phosphating, and should not be overlooked as an addition to the pasture and a means of soil improvement. 1½ pound of seed per acre is suggested to be mixed with the clover and grass wherever the land is to be used for pasture purposes.

CRIMSON CLOVER

Crimson clover is a valuable green-manure crop, but only rather fertile soils are well adapted to it. To get best results it should be sown by itself in middle or late summer, but under favorable conditions it may be sown in September. According to the Station's experiments seeding in corn at the last working is not apt to be successful.

LESPEDEZA

Lespedeza, or Japan clover, is not a true clover, but may be included with the others for practical purposes. Although found growing almost everywhere, it responds well to liming and phosphating, as was demonstrated at the West Tennessee Station. Under some conditions it may even be worth while to sow the seed. This may be done the middle of April. About 25 pounds per acre is required for a full stand the first year. Ten pounds, however, will be sufficient to give it a good start.

MELILOTUS

Melilotus, or sweet clover, is a legume but not a true clover. This plant requires, like alfalfa, a soil well supplied with lime; also soil inoculation with the same kind of bacteria required by alfalfa is apt to be necessary. It is probable that with attention to liming, phosphating, and inoculation, sweet clover can be used to some advantage as a green-manure crop. 25 or 30 pounds of seed per acre are recommended and the seeding may be done either in the spring, with oats, or in late summer without a nurse crop. The white-flowering variety rather than the yellow-flowering is preferred.

COWPEAS AND SOY BEANS.

The cowpea fruits extra well on Rim soils and is a seed crop of much promise for this section, especially as satisfactory threshers are now on the market. The standard variety is the Whippoorwill, but the late Black and the Clay variety are much used.

Soy beans and inoculation Soy beans may be grown to advantage both for hay and for grain, and have greater capacity for making heavy yields than the cowpeas. The writer has sometimes observed that soy beans when grown for the first time do not appear to be well inoculated, as indicated both by the light color of the foliage and also by the sparsity of the nodules on the roots. Continued growing of the beans on the same land would be expected to remedy the trouble, but soil inoculation may occasionally be advisable.

Soy-bean varieties On soils of average fertility only the late and vigorous varieties, such as Mammoth Yellow, Tokio, and Acme, are advised. The early varieties, such as Ito San and Haberlandt, which have done extra well at the Knoxville Station, are advised only for soils of rather high fertility. On poor land their growth is too dwarfed and meager.

For a more complete comparison between the cowpea and the soy bean, reference may be had to Bulletin 82 of this Station.

Fertilizers The fertilizer recommended for the red-colored limestone soils is 200 or 300 pounds of high-grade acid phosphate per acre. For the gray-colored soils of the Barrens type 200 or 300 pounds of the acid phosphate, together with 25 pounds per acre of muriate of potash, is advised.

GRASSES

The growing of grass should be considered one of the essentials to the most successful farming on Rim lands. Red-top is the common and generally most profitable grass, especially on the gray soils, but a mixture with Timothy is often sown. A number of experimental trials were made with other grasses, and both orchard and tall-oat were found to do well, the latter variety in particular having a great capacity for hay production. The best results were obtained from late August or early September seeding, and without a nurse crop. For hay a mixture of 33 pounds of tall-oat grass and either 12 pounds of red clover or 8 pounds of alsike per acre is recommended. Both lime and phosphate are generally essential for best results, and a light top-dressing of manure is very helpful. Clover not only adds to the yield but nourishes the grass. In the event of a failure of the clover, or after it has run out, a seeding of Japan clover may prove advantageous. For a thick stand the first season, 25 pounds of the Japan clover seed per acre is required, but 10 pounds will give it a good start for pasture purposes and is advisable in order to get a uniform stand as early as possible. In the absence of both clover and manure, the grass may be top-dressed with 80 or

100 pounds of nitrate of soda per acre, and this light application has sometimes been found to make the difference between success and failure.

Although the fall seeding of Timothy and red-top along with the wheat is a common practice, at least in some counties, spring seeding has given decidedly the best results in the Station's trials.

THE SMALL GRAINS

WHEAT

Wheat enters very nicely into most systems of crop rotation, and both the climatic and soil conditions of the Rim are favorable to it. The placing of this crop after corn should as a rule be avoided, although this may be done on soils of good fertility, especially if the corn be cut and shocked or removed for silage. Either cowpeas or soy beans, if removed early for hay, makes an excellent preceding crop.

Best varieties According to Station trials, which have been continued for 10 or more years, the best varieties of wheat for average upland are Fulcaster, Mediterranean, and Poole. Currell's Prolific and Fultz have also done well. For rich land, where the other varieties are apt to lodge, Fultzo-Mediterranean has proven superior to any other.

Fertilizers If the wheat be preceded by cowpeas, soy beans, or one of the clovers, or if a dressing or farmyard manure be made, then only acid phosphate at the rate of, say, 200 pounds per acre is advised as a fertilizer. Otherwise a complete fertilizer, such as recommended for corn, may be used. Under some circumstances a light dressing of, say, 40 pounds per acre of nitrate of soda may be profitably made in the fall, especially if the seeding be unduly delayed. Under usual conditions 60 to 100 pounds of nitrate may be applied in the spring, as soon as early growth starts, but the margin of profit is not great. Cotton-seed meal, dried blood, nitrate of soda, and other active forms of nitrogenous fertilizer are detrimental to the germination of seed with which they come into direct contact, and the later and more unfavorable the season the more pronounced is this effect. If any one of these materials be used, therefore, it should be drilled in separate from the seed. Acid phosphate, however, does not injure the germination, so that when used alone no precaution is necessary.

OATS

Both spring oats and winter oats are grown successfully on the Rim, but whenever possible winter oats rather than spring oats are advised. The winter or Gray Turf oat is the standard variety in common use. The Station found that the Culberson variety had some very desirable qualities, and has obtained from it a short-strawed selection which rarely lodges even on extra rich land, matures nearly two weeks earlier than the Turf oat, and is equally productive of grain.

Best varieties The Burt and the Kherson, or 60-Day Russian, are the best spring varieties. The latter is two or three days later than the former, produces somewhat more foliage, and has given a yield of grain fully equal to the Burt.

Time of seeding Winter oats should be sown earlier in the fall than any other small grain, or about the middle of September. Spring oats should be sown as early in the season as possible.

Oats and clover for hay A mixture of Culberson oats and either red or alsike clover for hay has been tried experimentally at a number of places with excellent results. A full seeding of each is advised, and the seeding should be done the latter part of August or early in September.

Fertilizers The same kind of fertilizers as recommended for wheat may be used for oats.

BARLEY

Winter barley is a rich-land crop, which does extra well on land too fertile for wheat. It is not, therefore, suited to average Rim soils. However, on account of its ready response to manuring, and its great capacity for grain production, it should receive more attention than it has received in the past. Seeding should be done the latter part of September in order to get the best results.

Spring barley is of little value, and has not proven equal to spring oats.

RYE

Rye is valuable chiefly as a grazing and cover crop, and also as a green-manure crop on very poor land. It can be sown with good results later than any other small grain, November and even December seedings being successful. October is probably the best month for seeding, but it is often sown in late August and September for pasture purposes.

Millet Hay—From Experiments on Highland Rim Soil.

No Fertilizer   Phosphate and Potash

Nitrate of Soda   Phosphate, Potash and Nitrate of Soda

MILLET FOR HAY

German millet, which is sown either alone or, better, with cowpeas for hay, responds well to rather heavy fertilization. Table VIII gives the average results obtained from five complete series of experiments, two conducted in different seasons on one farm, and each of the other three on different farms.

According to these and other trials on old land, 300 pounds of acid phosphate and from 80 to 160 pounds of nitrate of soda may be used per acre with fair assurance of profit. Also a small amount of muriate of potash may be used along with the acid phosphate—say 50 pounds for Barrens soil and 25 pounds for red lands—the two being mixed and well worked into the ground before seeding. The nitrate is advised to be applied broadcast as a top-dressing

soon after the plants come up. In the case of recently cleared land only acid phosphate is advised. Also it should be noted that in a mixture of millet and peas the phosphate and potash will encourage the growth of cowpeas in particular, but that the nitrate increases the growth of the millet much more markedly than that of the peas.

SORGHUM

The saccharine, or sweet, sorghums have long been grown on the Rim both for forage and for syrup. The Red Top variety is in common use for forage purposes, but the juice is too dark to make the best syrup. Tennessee-grown seed has proven to be superior to Western-grown seed. Amber, Orange, and other varieties are often grown for syrup-making purposes. Recent experiments by the Station have indicated, however, that the Honey variety, which is equally adapted to forage and to syrup making, is not only a far better yielder than any of the other varieties mentioned, but also is the least liable to lodge. It is therefore recommended as especially worthy of trial.

Sorghum may be planted either in rows and cultivated like corn or sown broadcast like millet. In either case cowpeas may be planted with it to advantage. For planting in rows, 6 to 8 pounds of seed are used for forage and about 4 pounds for syrup. A good mixture for broadcast seeding is 1¼ bushel of peas and ¾ bushel of sorghum. If sown in rows, ½ bushel of peas is ample.

The same kind of fertilizers recommended for corn may be used for sorghum.

The most serious trouble with sorghum sown broadcast is the difficulty of curing; and for this reason millet is often preferred, especially on fertile land. When planted in rows sorghum may be put into the silo with the best of results; otherwise it is cut and shocked before frost and will make excellent feed up to about New Year's. The planting in rows is advised for soil of good fertility, while broadcast seeding is adapted to the poor land where the sorghum does not grow too rank.

PEANUTS

An important crop

Peanut growing is an important industry in some counties of the Highland Rim and could be greatly extended. Gray-colored and easily tilled silt loams, both bottom and upland, are used. The low lands give the largest yields, but the rather common practice of raising peanuts on the same land year after year has greatly reduced their fertility. Undoubtedly a judicious crop rotation would do much to improve this condition, and either manure or crops like grass and clover will be needed to replenish the soil with vegetable matter. At present fertilizers are little used and liming is seldom if ever practiced.

Liming of little value to peanuts

The experimental results agree with respect to the direct effect of liming, which proved detrimental to the production of nuts, but appreciably increased the growth of tops. This does not exclude the possibility that lime will either act beneficially on other types of soil or be of much indirect value in peanut culture through its favorable effect on other crops, such as clover and grass.

Acid phosphate profitable

Acid phosphate was found to be highly profitable in various localities on Rim soils, but the addition of either a potash salt or a nitrogenous fertilizer was apparently not needed. The peanut is a leguminous plant, which gets much of the needed nitrogen from the air, but on extra poor soils, a little cotton-seed meal or nitrate of soda may possibly be used to advantage to give the plants a quick start. From 200 to 300 pounds of acid phosphate per acre is advised.

Varieties

Several tests have been made of the common varieties, such as Virginia White, both spreading and bunch types, Spanish and two kinds of Reds. The Spanish is the most productive and is strongly recommended for forage-crop purposes and also for home use, the flavor being superior to that of the other sorts. Favorable results have been obtained by the Station in the way of getting improved strains of several varieties by means of individual plant selection. In particular a stronger-hulled and slightly larger type of Spanish nut than that commonly grown has been gotten, and has been used in the cooperative trials.

TOBACCO

For the past six years fertilizer experiments have been conducted in Montgomery County in cooperation with successful tobacco growers. From twenty-five to thirty separate experimental plots were generally used at each place, so that valuable data were gotten. Much difficulty was experienced, however, in finding uniform soils adapted to experimental purposes, so that mention will be made here of only the following simple conclusions, which appeared to be well established:

1. The results obtained in eight out of nine series of experiments, in which six different farms were respresented, showed that the following mixture was used at a satisfactory profit:

300	lbs.	high-grade acid phosphate.
100	"	sulphate of potash.
400	"	cotton-seed meal.

This mixture analyzes—

6	per cent	available phosphoric acid
3¼	"	nitrogen
6	"	potash

The average for the nine series of the tobacco fertilized with the 800 pounds per acre was 1096 pounds of leaf, as compared with 748 pounds where no fertilizer was applied.

2. The results from seven series of experiments in which 160 pounds of nitrate of soda was compared with 400 pounds of cottonseed meal indicated that there was little choice between these two sources of nitrogen for the tobacco crop. An ample supply of both phosphate and potash was used on all plots in order to make the nitrogenous material effective. Also the soils used were poor in nitrogen.

3. As the average of five series of experiments there was found to be a gain of only 34.4 pounds of leaf tobacco per acre for each ton of farmyard manure used. In two of the series 12 tons of manure were used per acre, and in three series only 6 tons. Under the most favorable conditions there was an increase of 60.5 pounds of leaf for each ton of manure used.

4. Six tons of manure per acre, together with 800 pounds of the complete fertilizer mentioned, proved more profitable than either used alone.

5. Liming was tested on several farms, and at each place under a variety of fertilizer conditions, but no general conclusions can be drawn from the results, except that tobacco does not appear to be very responsive to liming. However, the indirect effect of liming, through the increased production of clover or other legume preceding tobacco, could not be other than beneficial.

CROP ROTATIONS

LIST OF ROTATIONS

A—GENERAL FARMING—FIVE-YEAR ROTATION

1st year—Corn, followed by winter cover crop for pasture and green manure.

2d year—Cowpeas or soy beans.

3d year—Wheat or other small grain.

4th year—Clover and grass.

5th year—Clover and grass.

B—GREEN MANURE AND GRAIN—THREE-YEAR ROTATION

1st year—Corn, followed by winter cover crop for pasture and green manure.

2d year—Cowpeas or soy beans.

3d year—Wheat, followed by crimson clover for green manure.

Note—A most excellent rotation wherever crimson cl ver does well.

C—GENERAL FARMING—THREE-YEAR ROTATION (OR LONGER IF DESIRED)

1st year—Corn.

2d year—Wheat.

3d year—Clover, or clover and grass for two or more years.

Note—This is a well-known rotation, which has been followed successfully in many instances, but under average conditions Rotation A is considered to be decidedly preferable.

D—PASTURE FOR HOGS—TWO-YEAR ROTATION

1st year—Corn and cowpeas.

2d year—Rye, sown in fall, and alsike or red clover, sown in spring.

E—PASTURE FOR HOGS—TWO-YEAR ROTATION

1st year—Red or alsike clover and barley.

2d year—Soy beans or cowpeas.

GUIDE IN THE ESTABLISHMENT OF A ROTATION

The writer has prepared Table IX with the view of furnishing a practical guide during the establishment of the five-year general farming rotation. The spring of the year 1914 is taken as the commencement of the project and it is assumed that the land is in an ordinary state of fertility. According to this plan the rotation will not be in full operation until 1916; at least two years being required to accomplish this result.

TABLE IX—*Five-year crop rotation (No. 1), showing crops, amount per acre of fertilizers, etc., suggested for each field during the establishment of the rotation—based on experiments conducted on gray-colored soils of Highland Rim—all operations assumed to begin in spring of 1914*

FIELD 1	FIELD 2	FIELD 3	FIELD 4	FIELD 5
1914 — Corn—followed with winter cover crop Acid phosphate 200 lbs., muriate of potash 20 lbs., cotton-seed meal 100 lbs.	1914—Cowpeas. Acid phosphate 300 lbs., muriate of potash, 50 lbs.	1914—Soy beans. Acid phosphate 300 lbs., muriate of potash 50 lbs.	1914—Spring oats. Acid phosphate 200 lbs., muriate of potash 20 lbs., nitrate of soda 100 lbs.	1914—Spring oats. Acid phosphate 200 lbs., muriate of potash, 20 lbs., nitrate of soda, 100 lbs.
1915—Soy beans. Acid phosphate 300 lbs., muriate of potash, 50 lbs.	1915—Wheat. (Sown in Oct., 1914). Ground limestone 2 tons, acid phosphate 200 lbs. in fall and manure 6-10 tons top-dressed during the winter.	1915—Corn — followed with a winter cover crop. Acid phosphate 200 lbs., muriate of potash 20 lbs., cotton-seed meal 100 lbs.	1915—Red clover. (Sown late in Aug. or early in Sept., 1914.) Ground limestone 2 tons, acid phosphate 300 lbs., muriate of potash 50 lbs.	1915—Clover and grass. (Sown late in Aug. or early in Sept., 1914.) Ground limestone 2 tons. acid phosphate 300 lbs., muriate of potash 50 lbs.
1916—Wheat. (Sown in Oct., 1915). Ground limestone 2 tons, acid phosphate 200 lbs. in fall, manure 6-10 tons, top-dressed during the winter.	1916—Clover and grass (Sown in spring, 1915.)	1916—Soy beans. Acid phosphate 300 lbs., muriate of potash 25 lbs.	1916—Corn. Acid phosphate 200 lbs., muriate of potash 20 lbs. Follow with winter cover crop.	1916—Clover and grass (for hay and pasture.)
1917—Clover and grass. (Sown in spring, 1916.)	1917—Clover and grass (for hay and pasture).	1917—Wheat. (Sown in Oct., 1916.) Ground limestone 2 tons. acid phosphate 200 lbs. in fall, manure 6-10 tons, top dressed during winter.	1917—Soy beans. Acid phosphate 300 lbs., muriate of potash 25 lbs.	1917—Corn — followed with winter cover crop. Acid phosphate 200 lbs., muriate of potash 20 lbs.
1918—Clover and grass (for hay and pasture.)	1918—Corn — followed with winter cover crop. Acid phosphate 200 lbs., muriate of potash 20 lbs.	1918—Clover and grass. Sown in spring, 1917.	1918—Wheat. (Sown in Oct., 1917.) Acid phosphate 200 lbs. in fall, manure 6-10 tons, top-dressed during winter.	1918—Soy beans. Acid phosphate 300 lbs., muriate of potash 25 lbs.

It may be noted that after the establishment of the rotation—1916 and later—a change is made in the commercial fertilizers, both for corn and for the small-grain crop. This change consists in the omission of both the cotton-seed meal and the muriate of potash. In the case of the rye, the manure would much more than replace these two ingredients and the residues from the clover and grass would be expected to furnish an appreciable supply of nitrogen for the corn which follows. Also in case of freshly cleared land neither meal or potash salt is advised from the outset.

NOTES ON TABLE IX

1. The liming may be done sooner than directed in the table. In fact, although especially beneficial to clover, liming is apt to increase the yield of any of the crops to an appreciable extent. According to our experimental evidence, two tons of ground limestone will be ample for at least five years, and possibly for twice that length of time.

2. The acid phosphate and muriate of potash should always be applied before planting the crop for which they are especially intended, and give best results when applied in the row for crops planted in rows. For broadcast-sown crops these materials may be applied broadcast before the land is turned, or may either be drilled in afterward or scattered broadcast and well harrowed into the soil.

3. As a cover crop after corn, to prevent loss during the winter, choice may be had of wheat, rye, crimson clover, and hairy vetch. Crimson clover is an ideal crop in some respects, but requires a rather fertile soil in order to thrive. Even then, when sown in corn at the last working, it is apt to be killed before winter by dry, hot weather. Rye would help to hold the crimson clover from freezing out during the winter, and the mixture may be sown considerably later than crimson clover alone. Hairy vetch can be sown later than crimson clover and any time during September is favorable, provided the soil-moisture supply be good. If sown in early October it is apt to go through the winter. Like crimson clover it may be sown with either rye or wheat. Rye can be sown later than wheat and makes the earliest spring growth.

The cover crop should be turned under at a rather early stage of growth—in the case of rye and wheat not later than when in boot; but for crimson clover and vetch when in early bloom. Attention is called to the fact that vetch makes only a small growth during the fall, winter, and early spring, and is a vigorous grower only after warm weather comes in the spring; so that to get the most good out of this crop for green-manure purposes it must remain on the land later by several weeks than either of the others, or until about the middle of May. This would not, however, be a serious objection, as either cowpeas or soy beans can be planted to advantage after this date.

4. The manure is advised as a top-dressing on the wheat for the special purpose of getting a good stand of clover and grass from a spring seeding. If the land is of such quality that the manure is not needed for this purpose it may well be applied for the corn crop, which offers a greater possible increase in grain than the wheat.

In the absence of manure an extra amount of both the phosphate and potash is advised.

5. Either red or alsike clover may be used, and a mixture of the two is sometimes advisable. Alsike when sown in late summer or early fall would be expected to produce an appreciable part of the hay crop of the next two years, but red clover is apt to disappear after the first year. When spring-sown, one lasts about as long as the other, provided the red clover disease, which does not affect the alsike, is not serious.

In the case of a failure of clover, in the spring following the seeding an application of 100 pounds per acre of nitrate of soda may be made to advantage for the grass, and should be applied as early in March as the spring growth begins.

In case of a poor stand of both clover and grass at the beginning of the second year a seeding of 25 pounds per acre of Japanese clover (Lespedeza) about the first of April is recommended.

6. For the red-colored soils of limestone origin the same fertilizers, etc., may be used, except that the potash can be reduced by one-half.

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THE INFLUENCE OF AMMONIUM CARBONATE UPON THE DETERMINATION OF HUMUS

A RAPID AND EFFICIENT FILTRATION PROCEDURE

BY

W. H. MACINTIRE

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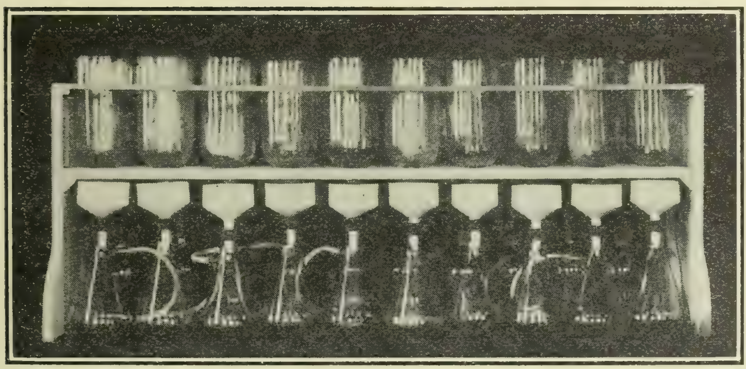

BATTERY OF FILTERS FOR WASHING AND FILTERING SOILS

KNOXVILLE, TENNESSEE

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OF THE UNIVERSITY OF TENNESSEE

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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State

THE INFLUENCE OF AMMONIUM CARBONATE UPON THE DETERMINATION OF HUMUS

A RAPID AND EFFICIENT FILTRATION PROCEDURE*

BY

W. H. MacIntire

AND

J. I. Hardy

INTRODUCTION

The original Grandeau method[1], for the determination of humus, as modified by Huston and McBride[2], and adopted as official by the Association of Official Agricultural Chemists[3], has been the subject of much study and criticism. As the result of various investigations the Association at its 1913 meeting eliminated the determination from its approved methods, because of the apparent unanimity of opinion as to the unreliability of the method, due to the presence of suspended clay, and hydrated iron, etc., in the filtrate obtained by the official procedure.

Frear and Beistle[4], in 1901, showed the unreliability of the official method. In 1906, Peters and Averitt[5] announced discontinuation of the determination in regular work at the Kentucky Station and at the same time noted the use of their 10 per cent correction for combined water, as applied to ash. Mooers and Hampton[6] found a correction of 14 per cent to give more concordant results, while Fraps and Hamner[10] concluded a correction of 8 per cent should be applied.

Methods suggesting modified procedures and studies of various proposed methods have been reported by Mooers and Hampton[6], Stoddart[7], Hilgard[8], Cameron and Breazeale[9], Fraps and Hamner[10], Snyder[11], Alway, Files and Pinckney[12], Leavitt[13], Wells, Stevenson, and Coover[14],

* A modification of the Rather procedure.

Kelly and McGeorge[15], Rather[16], Smith[17], and Brown and MacIntire[19a], upon gravimetric methods, and by Beam[18] (see footnote) upon a colorimetric estimation.

Prior to the publication of the work of Rather and Smith, it seemed to be the consensus of opinion among those who reported investigations upon the subject, that the Mooers-Hampton method was the most dependable modification advanced for the determination of humus, and it was, and is, widely used as a basis of comparison for proposed modifications. It is, however, foreign to the purpose of this article to enter into a discussion of those factors of merit and limitation which various investigations have shown to influence the value of the different modifications which have been proposed.

While the accuracy of the method for the determination of humus, as modified by Mooers and Hampton, has been widely recognized, and is esteemed by the authors, it is nevertheless true that the time involved in the technique of its manipulation is a serious hindrance to rapid work under normal laboratory conditions. Confronted with the necessity of making some hundreds of humus determinations at frequent intervals upon a comprehensive set of field experiments, the authors sought a method embodying both speed and accuracy. The Rather and Smith methods both seemed to possess more than ordinary possibilities, and in a comparative study of these two methods the data given in this article were secured.

RATHER[16] AND SMITH[17] METHODS

The modification of Rather as given by Fraps[19] directs the usual elimination of lime and magnesia and 24-hour digestion with 4 per cent ammonium hydrate, but the supernatant solution is then decanted from the cylinder and the ammonium carbonate introduced into the decanted portion at the rate of 2½ grams per 500 c. c. and the cylinder containing the treated solution left in an upright position overnight, after which the

Footnote—The use of the Buchner funnel in the determination of humus was recorded by Brown and MacIntire in the 1908-09 Pennsylvania Station Report[19a], and since that time it has been used by the writer to the exclusion of all other filters in preliminary steps of humus determinations. The use of the Pasteur-Chamberlain filter tube originally suggested by Frear and Beistle[4] (1901) and later by Cameron and Breazeale[9] (1904), and by Kelly and McGeorge[15], was mentioned as being the medium of filtration of the solutions used in the analyses given in the article cited. The apparent assumptions of priority of claim to these innovations were doubtless due to the obscureness of the articles mentioned or to inaccessibility of the limited editions of the Pa. Sta. Annual Reports.

Subsequent to the preparation of the data of this bulletin (Jan. 1914), the reprint of the Cairo Scientific Journal, 85, Oct., 1913, was received in this laboratory and, other than abstracts, constituted the first knowledge on the part of the authors of the work of Beam. The studies reported in this publication were begun in June, 1913 and part of the data secured by the modification offered in this article was given with exhibits in a paper read before the A. O. A. C. at its Nov., 1913, meeting—W. H. MacIntire.

solution is filtered by gravity through dry filters. The filtrate is then evaporated, dried and ignited in the usual manner. The Smith modification directs the removal of lime and magnesia and contact of soil with 4 per cent ammonium hydrate for 24 hours. The ammoniacal mixture is then agitated and thrown upon large cone-shaped funnels having filters with hardened points. The cloudy portion first coming through is discarded or returned to the filter. Periods of from 2 to 12 hours are required to secure perfectly clear solution, the additional overnight filtration giving sufficient of filtrate for duplicate determinations.

FILTRATION OF HUMUS SOLUTION THROUGH BUCHNER FUNNELS BY SUCTION

For the gravity cone filtrate used by Smith, the authors substituted the perforated porcelain disc of the Buchner funnel (Fig. 1) as used by Brown and MacIntire, 1908[19a], and found the filtration period for 500 c. c. of filtrate to be shortened to less than 7 hours. It was found, as cited by Smith[17], that in every case the ash of the straight filtration was higher in percentage and also redder in color than that of the Rather method when working upon loam soils. With the above modification the Smith method, though efficient, was still not sufficiently rapid for the purposes in view, and the Rather method was then modified by the introduction of 2½ grams of ammonium carbonate into the ammoniacal solution at the end of the 36-hour contact period of soil with ammonia, and filtration accomplished immediately after the carbonate had entirely dissolved in the hydrate solution. The soil mixture was agitated and thrown upon *two* 597 S. & S. filters laid on the porous porcelain disc (Fig. 1) with about 2 inches vacuum, which later was increased, wtih some soils to from 5 to 20 inches after the filter bed had been made. The introduction of ammonium carbonate so quickened the speed of filtration that 50 filtrations of 300 c. c. each were made by two men in one day, while but 10 could be made by straight filtration with suction without carbonate, batteries of 10 filters being used in each case. *It was found that violent agitation after the addition of ammonium carbonate increased deflocculation and tended to retard filtration, gentle mixing giving the greater speed.* By straight filtration with suction the passage of 100 to 150 c. c. portions was required to clarify thoroughly, while filtrates of but 15 c. c. were necessary to insure absolute clearness after the addition of ammonium carbonate.

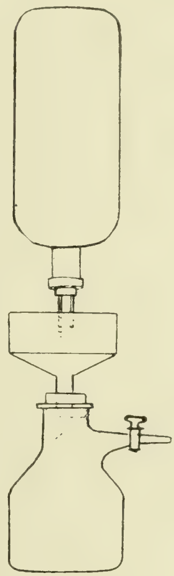

Fig. 1

COMPARISON OF MODIFICATION WITH ORIGINAL RATHER METHOD

The modified filtration by suction was then compared with the original Rather method in its effect upon the quantities of ash. One hundred and two (102) determinations by the Rather method upon the same soil, a Cumberland loam, gave an average ash content of .33 per cent, with variations from .24 to .52 per cent, while .18 per cent represented the average of two hundred and seventy-four (274) analyses on the same soil by the modified procedure of filtration, variations being from .11 to .24 per cent. Furthermore, though apparently clear at time of filtration, the solution obtained by the Rather method gave a sediment upon standing four months, while none has occurred after six months in the solutions obtained by the modified procedure. *Analyses demonstrated that the modified procedure lessens the ash obtained by straight filtration; shortens the determination and reduces the ash obtained by the Rather method; reduces the period of contact of soil with ammonium carbonate (later shown to be an important factor); eliminates the period required by the Rather method for flocculation; and increases fivefold the speed of straight filtration without carbonate.*

VARIATIONS IN THE HUMUS CONTENT OF AMMONIA SOLUTIONS CONTAINING CARBONATE, UPON STANDING

In making the filtrations by the modified procedure, 250 to 300 c. c. of filtrates were obtained and the residues were left in the cylinders. Whenever duplicate determinations failed to agree within a limit of .05 per cent second filtrates were secured for another pair of determinations. It was noted that these second filtrates in every case ran higher than the initial filtrations. With the intention of determining whether this was a mere laboratory coincident or the result of prolonged solvent action of ammonia or ammonium carbonate when in contact with the soil, 18 determinations were made upon filtrates from one soil immediately after addition of ammonium carbonate and compared with 18 analyses of second filtrations secured by filtering the residue which had remained in contact with ammonia and ammonium carbonate for 8 days. An average of the 18 determinations on the first filtrate gave 1.18 per cent humus, while the 18 analyses of the second filtrate gave an average of 1.40 per cent. With the intention of throwing some light upon this constant phenomenon, the analyses given in Table 1 were made.

TABLE I—*Influence of period of contact of soil with ammonium hydrate alone and ammonium hydrate and varying amounts of ammonium carbonate**

Soil	Method of treatment	Time of contact with NH_4OH	Per cent humus				Per cent ash			
			A	B	C	Avg.	A	B	C	Avg.
Cumberland loam	Straight filtration	36 hours	1.29	1.20	1.38	1.29	.53	.53	.62	.56
"	"	8 days	1.25	1.31	1.28	1.28	.37	.37	.37	.37
"	2.5 gms. carbonate in contact	36 hours	.98	.99	1.09	1.02	.15	.15	.21	.17
"	"	8 days	1.09	1.10	1.09	1.09	.16	.18	.17	.17
"	2.5 gms. carbonate at time of filtration	36 hours	1.03	1.05	1.17	1.08	.18	.18	.21	.19
"	"	8 days	1.30	1.29	1.31	1.30	.21	.18	.20	.20
"	25.0 gms. carbonate in contact	36 hours	.77	.80	.87	.81	.12	.13	.18	.14
"	"	8 days	.86	.87	.88	.87	.16	.14	.15	.15
Virgin meadow soil	Straight filtration	36 hours	4.35	4.28	4.36	4.33	.53	.67	.81	.67
"	"	8 days	4.90	4.88	4.89	4.89	.91	.95	.88	.91
"	2.5 gms. carbonate in contact	36 hours	3.87	3.87	4.00	3.91	.41	.39	.40	.40
"	"	8 days	4.21	4.11	4.18	4.17	.34	.36	.35	.35
"	2.5 gms. carbonate at time of filtration	36 hours	3.44	3.49	3.93	3.62	.33	.38	.31	.34
"	"	8 days	5.12	4.92	4.94	4.99	.86	.87	.82	.85
"	25.0 gms. carbonate in contact	36 hours	2.62	2.60	2.81	2.68	.25	.29	.29	.28
"	"	8 days	3.18	3.14	3.12	3.15	.23	.27	.22	.24

* 4 per cent NH_3 is used in this and all subsequent tables. Corrections were made for combined water of ash of all results in tables on the basis of 14 per cent. Changes of volume resulting from treatment are also corrected for.

INVESTIGATION OF SOME POSSIBLE FACTORS AFFECTING THE INFLUENCE OF AMMONIUM CARBONATE UPON ESTIMATION OF HUMUS

The preliminary analyses, supplemented by those of Table I, indicated a number of possibilities arising from the activity of ammonium carbonate when introduced into the ammoniacal solution. As factors affecting the phenomena observed, the following possible influences were investigated:

1. The effect of increased period of contact of soil with ammonium hydrate alone.

2. The difference in solvent action of the ammoniacal solution, resulting from change in concentration through possible dissociation and decomposition of ammonium carbonate, or through reaction between impurities of acid carbonate and ammonium hydrate.

3. The occlusion of organic matter by the carbonate during short period being greater than solvent action of the ammonia during the same period.

4. The solvent action of ammonia during long periods overcoming the occlusion originally effected by the carbonate.

5. The possible chemical precipitation of humus by the carbonate at first, as well as formation during the long contact period of some compounds of volatile points higher than 100°C. by reaction of humus extract with ammonium carbonate.

6. The possible physical absorption or inclusion of traces of carbonate in the humus mass while drying.

7. The solvent action of ammonium carbonate varying with period of contact with soil.

EFFECT OF TIME OF CONTACT OF SOIL WITH AMMONIUM HYDRATE

Huston and McBride[20] studied the effect of periods of contact of ammonia upon peat soils, using 2 per cent ammonia, and found increased solvent action with longer period. Fraps and Hamner [21] attribute this to the manufacture of humus by chemical action upon the peat material. As bearing upon the factor of period of contact, Table II is quoted from Wiley[22].

TABLE II—*Influence of time of digestion, Huston method,* 4 *per cent ammonia*

	36 hours	48 hours	68 hours	98 hours
Peat soil	21.24	22.28	24.04	.....
Good soil	20.20	21.91	23.99	.....
Clay loam	4.28	4.00	....	4.40
Clay loam	4.26	4.01	.....	4.85

The analyses of Table II were not corrected for ash, the amounts of which were not given, and the differences shown would probably be considerably altered by correction of the ash occurrence. The data given in Table III, hitherto unpublished, represent duplicate determinations by the Mooers-Hampton method, with correction, and were made by Mr. H. H. Hampton, formerly of this Station, under the direction of Prof. C. A. Mooers.

TABLE III—*Effect of period of contact of soil with 4 per cent NH_4OH*

Soil	Two days		Two weeks	
	Per cent humus	Per cent ash	Per cent humus	Per cent ash
571..................	.65	.17	.66	.16
575..................	.63	.14	.69	.14
577..................	1.73	.65	1.72	.69
581..................	1.00	.20	1.01	.16
582..................	.42	.11	.46	.12
605..................	3.06	.94	3.09	.93
Average	1.25	.37	1.27	.37

The analyses of Hampton would indicate that the usual contact period is sufficient for complete solvent action upon the more common types of soil. In order to study the factor of time of contact of the soils of Table I with ammonia the analyses of Table IV were made. The loam soil is a fairly fertile Cumberland loam and the black soil is a virgin meadow soil secured from Massachusetts.

TABLE IV—*Influence of time of contact of soil with ammonia—filtration by modified procedure,* 1 *gram of carbonate at time of filtration*

Time of contact	3 hours		12 hours		40 hours	
	Per cent humus	Per cent ash	Per cent humus	Per cent ash	Per cent humus	Per cent ash
Loam soil 2584	1.04	.20	1.11	.19	1.15	.24
”	1.06	.18	1.13	.14	1.15	.23
	1.06	.23	1.13	.15	1.19	.21
”	1.04	.19	1.08	.16	1.16	.22
Average	1.05	.20	1.11	.16	1.16	.23
Black soil 3120a	4.72	.63	5.14	.62	5.52 5.38	.60 .67
”	4.65	.61	5.22	.63	5.49 5.43	.61 .67
”	4.65	.67	5.18	.55	5.42 5.39	.62 .67
”	4.72	.63	....	....	... 5.45	... .67
Average	4.69	.64	5.18	.60	5.44	.65

The figures of Tables III and IV are in accord with observations previously cited, and indicate that the two-nights-and-one-day contact period is to be preferred to shorter periods.

EFFECT OF CHANGE OF STRENGTH OF AMMONIA DIGESTION SOLUTION CAUSED BY INTRODUCTION OF AMMONIUM CARBONATE

Fraps and Hamner[23] and Alway, Files and Pinckney[12] in comprehensive studies of the solvent action of various strengths of ammonia have shown the greater solvent action of the stronger solutions. Wiley[22] has shown the same upon peat soils, and Huston and McBride[20] recorded the same observations and noted the effect of temperature upon solvent action. By the writers it was at first thought possible that the increases in percentages of humus obtained in filtrates secured after long contact of soil with ammonia and ammonium carbonate over the filtrates obtained by immediate filtration might be due to increased alkalinity resulting from dissociation and decomposition of ammonium carbonate, effected by the possible difference in the soil's selective absorption of NH_3 and CO_2. Accordingly the two soils 2723 and 2995 were left in contact with distilled water containing 1 gram, 2½ grams, and 25 grams ammonium carbonate, free gases being first removed from the solution by 1½ hour's aspiration, before the introduction of the acid-washed soil into the cylinders. After standing in contact with the soil for 36 hours no odor of ammonia was noticed in the 1 and 2½-gram treatments, but considerable was found in the 25-gram charges. This would indicate that the increased amounts of humus found in the 18 original determinations, where the soil was in contact with ammonium carbonate solution for an 8-day period, were not due to the soil mass effecting any decidedly increased strength of the ammoniacal solution. The percentages of humus determined by this treatment are given as a part of Table X. The data of Table I, however, show less of solvent action in the case of the 25-gram carbonate treatment than where the smaller amounts were used. The ammonium carbonate used emitted a strong odor of ammonia and was examined for occurrence of acid ammonium carbonate. Two samples of Kahlbaum's C. P. ammonium carbonate, one crystalline, the other hard, white, porous lumps, both protected from access of air, and one of Mallinckrodt's C. P. carbonate, were tested by alcohol solution and found to contain considerable quantities of acid carbonate. As shown later in this paper, in the study of the solvent action of ammonium carbonate, theoretically the strength of the 4 per cent ammonia solution would be decreased through the conversion of the acid carbonate into the normal carbonate. Assuming 50 per cent of the 25-gram charge of carbonate to be acid carbonate, the ammonium hydrate used for conversion of the acid carbonate to normal carbonate would decrease the strength of the 4 per cent NH_3, 13.45 per cent. This decrease was corrected for by use of concentrated ammonia and determinations were made upon solutions obtained by di-

gesting a rich soil, 3120a, with ammonia and 25 grams of ammonium carbonate with and without the additional NH_4OH, calculated as necessary to correct the assumed error due to the presence of 12.5 grams of ammonium acid carbonate.

TABLE V—*Effect of reduction in strength of NH_3 by reaction with ammonium acid carbonate in the heavy carbonate treatment*

Treatment	1 gm. $(NH_4)_2CO_3$ at filtration		25 gm. $(NH_4)_2CO_3$ at filtration		25 gm. $(NH_4)_2CO_3$ at filtration plus correction for 12.5 grams acid carbonate	
	Per cent humus	Per cent ash	Per cent humus	Per cent ash	Per cent hnmus	Per cent ash
Soil 3120a	5.38	.67	3.26	.22	3.60	.22
	5.39	.67	3.22	.22	3.63	.23
	5.43	.67	3.16	.26	3.55	.26
	5.42	.62	3.20	.23	3.89	.24
Average	5.41	.66	3.21	.23	3.67	.24

These analyses, supplementing those of Table I, indicate that the decrease observed in every case of 25-gram treatment can not be attributed, to any appreciable extent, to decrease of akalinity through reaction between acid carbonate of ammonia and ammonium hydroxide. This phase of the subject is given more in detail elsewhere in this paper.

OCCLUSION OF ORGANIC MATTER BY ACTION OF AMMONIUM CARBONATE AND THE DECREASE IN OCCLUSION ON STANDING FOR LONG PERIODS

The probability of precipitation of humus resulting from the use of ammonium carbonate in the ammoniacal solution has been suggested by Beam[24], Smith[25], and Kelly and McGeorge[29], while Fraps and Hamner[26] show that clays precipitated by means of sulphate and chloride of ammonia contain organic carbon. Data offered in Table I show unquestionably an occlusion or precipitation of humus, resulting from the introduction of ammonium carbonate into the ammoniacal solution, and apparently the decrease of humus from the solution is in a measure proportional to the amount of carbonate used. The analyses of Table I also show that the period of contact of soil with the carbonate is an important factor in the extraction of the alkali-soluble soil organic matter. The occlusion which is apparent in short-time contact is to an appreciable extent overcome by the solvent action of the ammonia or ammonium carbonate upon long standing, or else the physical readjustment of the soil particles when acting as a filter bed, is such that less of the humus is retained in the soil filter bed during the filtration subsequent to long standing.

COMPARISON OF ACTION OF DIFFERENT FILTER BEDS

In order to determine the effect of different amounts of soil when used as filter beds for filtration by suction, the entire soil mass of 10 grams was agitated and thrown upon the disc filter, the resulting filtrate being compared with that obtained by filtration through a bed formed by suspended material contained in the upper 450 c. c. of a 500-c. c. extraction, which had settled 30 minutes subsequent to the last agitation in the 36-hour period of contact. The influence of large and small additions of carbonate upon the efficiency of the two beds was also observed.

TABLE VI—*Comparison of effect of filtration by use of entire soil mass as a filter bed, with that of a bed made by the upper 450 c. c. of solution—contact with ammonia for 36 hours. Ammonium carbonate added at time of filtration.*

Soil	Treatment	Per cent humus				Per cent ash			
		A	B	C	Avg.	A	B	C	Avg.
Loam 2723	2.25 gm. $(NH_4)_2CO_3$ to upper 450 c. c.	1.05	1.08	1.09	1.07	.24	.23	.23	.23
"	2.50 " " to entire mixture	1.03	1.05	1.17	1.08	.18	.18	.21	.19
"	22.50 " " to upper 450 c. c.	.98	.92	1.03	.98	.16	.17	.17	.17
"	25.00 " " to entire mixture	.77	.86	.87	.81	.12	.13	.18	.14
Virgin 2995	2.25 " " to upper 450 c. c.	4.51	4.51	4.62	4.55	.73	.75	.77	.75
"	2.50 " " to entire mixture	3.44	3.49	3.93	3.62	.33	.38	.31	.34
"	22.50 " " to upper 450 c. c.	2.87	2.90	3.03	2.93	.27	.27	.26	.27
"	25.00 " " to entire mixture	2.62	2.60	2.81	2.68	.25	.29	.29	.28

The data of this table show no difference between the occlusion of the entire mass and that of the suspended portion of the loam soil, but greater occlusion by the entire mass than of the suspended portion of the virgin soil. Additional amounts of quartz sand added to this mass were found to give still further occlusion in the black soil, but no effect was produced in the loam soil. The differences are striking, in that a large amount of clay, usually the constituent causing most trouble in filtration, is present in the loam soil and apparently but very little is contained in the black soil, which is composed of very fine sand. This black virgin soil is more difficult of filtration than the clay soil, and there seems to form upon the surface of the filter a gelatinous substance resembling iron hydrate, which retards filtration. The table also demonstrates conclusively that the lower results obtained by the use of large amounts of carbonate are due to occlusion, which increases with the quantity of carbonate used. The comparisons indicate further that the ability to retain humus is more especially attributable to the very finely divided clay and silt which do not settle out from 4 per cent ammonia solution in 30 minutes, and also that the amount of soil comprising the filter is in some cases an important factor. Filtrations accomplished by use of entire soil mass were more rapid than those secured through beds formed by the suspended material in the upper portion of the mixture.

With both soils the ash content was lower when the entire mass was used for filtration, and percentage of ash decreased coincidentally with the increasing amounts of carbonate added. The amount of carbonate used caused greater differences than the difference in the mass of the filter bed.

OCCLUSION OF HUMUS BY THE ORIGINAL RATHER PROCEDURE

In his original report Rather[27], after correcting for combined water of ash on a basis of 10 per cent, found by the Mooers-Hampton method 1.55 per cent humus, as an average of 12 soils, and 1.39 per cent as an average by the Rather method on the same soils. On correcting the mathematical errors in the last line of the third, fourth, and fifth columns of the table given by him, it is found that his 6 richest soils gave an average of 2.28 per cent by the Mooers-Hampton method and 2.08 per cent by the Rather method, a difference of .20 per cent, while the 6 lowest determinations gave .83 per cent by the Mooers-Hampton method and .71 per cent by the Rather method, a difference of .12 per cent. The greatest difference, .39 per cent, occurs with the largest percentage of humus, and the differences between the two methods appear proportional to the amount of organic matter present. These differences seem to be in accord with observations made from analyses given in this article. The assumption by Rather seems to be that these differences are attributable to constant error in the Mooers-Hampton method, even after applying a 10 per cent correction throughout to the ash, which as obtained by the Mooers-Hamp-

ton modification is somewhat higher than that found by the Rather procedure. As a matter of fact the errors entering into the Mooers- Hampton method, i. e., possible oxidation and occlusion of organic matter in the dehydrated silica, are calculated to cause lower than true results, as noted by Hanner[28], Kelly and McGeorge[29], and others. Since the Mooers-Hampton method gives higher averages than the Rather procedure, at the same time possibly less than absolute results, it would seem fair to assume that the Rather method results are still further removed from the actual percentage occurrence of humus. The figures given in this article indicate an occlusion of humus in the Rather procedure as accounting for the difference between the results by the two methods.

VARIATIONS IN OCCLUSION EFFECTED BY DIFFERENT AMOUNTS OF AMMONIUM CARBONATE

After observing that the occlusion of humus is apparently proportional to the amount of $(NH_4)_2CO_3$ present, the quantity of the carbonate used was reduced to 1 gram. The speed of filtration by suction was found to be practically as rapid with 1 gram as that resulting from the use of 2½ grams of carbonate. At the same time, 1 gram used in the original Rather procedure did not cause perceptible flocculation after standing 6 weeks. Comparisons were then made between the solutions obtained by straight filtration through the Buchner disc filter by suction and those obtained by filtration with carbonate added at the end of a 36-hour period of contact between soil and ammonia. This brought the carbonate into contact with the soil only during the period of 1 to 1½ hour required for filtration by suction.

TABLE VII—*Effect of addition of* 1, 2½ *and* 25 *grams of* $(NH_4)_2CO_3$ *before filtration, compared with straight filtration*

	Treatment	Per cent humus				Per cent ash			
		A	B	C	Avg.	A	B	C	Avg
Loam soil	Straight filtration	1.29	1.20	1.38	1.29	.53	.53	.62	.56
"	1 gm. $(NH_4)_2CO_3$	1.29	1.24	1.32	1.28	.29	.27	.32	.29
"	2½ gm. "	1.03	1.05	1.17	1.08	.18	.18	.21	.19
"	*25 gm. "	.77	.80	.87	.81	.12	.13	.18	.14
Virgin soil	Straight filtration	4.35	4.28	4.36	4.33	.53	.67	.81	.67
"	1 gm. $(NH_4)_2CO_3$	4.52	4.45	4.58	4.52	.70	.69	.70	.70
"	2½ gm. "	3.44	3.49	3.93	3.62	.33	.38	.31	.34
"	*25 gm. "	2.62	2.60	2.81	2.68	.25	.29	.29	.28

*Contact 36 hours.

The analyses of Table VII show decrease of humus percentages in every case coincidentally with the increasing amounts of ammonium carbonate above 1-gram additions. The ash content also decreases with the

increase of carbonate. Kelly and McGeorge[29] found a very decided decrease in both humus and ash in Hawaiian soils when the ammonium carbonate treatments were increased from 2½ grams to 20 grams per 500 c. c., and the Rather procedure followed. Apparently any occlusion occurring from the use of 1 gram of carbonate, is compensated for by solvent action of the carbonate (given later in this article) or other factors. The data given beginning with Table I show interesting differences, but the striking results are more intensely interesting when they are so clearly defined to the eye through the decided differences in colors of the extracted solutions.

UNIFORMITY OF COMPOSITION OF DIFFERENT PORTIONS OF HUMUS FILTRATES OBTAINED BY MODIFIED PROCEDURE

Studies of Alway, Files and Pinckney[12], and Kelly and McGeorge[15] demonstrated that the latter portions of filtrates obtained by passage through Pasteur-Chamberlain filter tubes were lighter in color and lower in humus content than the extracts first passing through. In order to determine any differences between the first and last portions as filtered through a filter bed made from the entire mass of soil, the analyses of Table VIII were made. Humus extractions were secured from 6 different soils representing 6 distinct soil types and 6 different treatments, including lime alone and lime and magnesia, with manure. A composite of these 6 extractions was made by taking 225-c. c. portions of the first 250 c. c. coming through, and compared with a corresponding composite of the 6 filtrates obtained by the second portions being filtered through the same filter bed. The suction used in this work was purposely varied from 2 to 25 inches, and there seems to be no difference resulting from variations in pressure. Comparison of the two filtrates in a Shreiner colorimeter showed the two filtrates to be identical in depth of color.

TABLE VIII—*Composite of extractions of humus from six different soils representing four distinct soil types*

	Composite of first portions		Composite of second portions	
	Per cent humus	Per cent ash	Per cent humus	Per cent ash
	1.45	.19	1.54	.18
	1.46	.18	1.47	.24
	1.48	.19	1.48	.23
	1.45	.18	1.50	.24
	1.43	.21	1.51	.21
	1.45	.20	1.48	.23
Average	1.45	.19	1.49	.22

POSSIBLE REACTION BETWEEN AMMONIUM CARBONATE AND HUMUS MATERIAL IN SOLUTION OR INCLUSION OF CARBONATE WITHIN THE MASS OF HUMUS

The extracted organic matter commonly spoken of as humus is admittedly a very complex substance, the composition of which is little understood. According to Storer[30], "Little is known as yet as to the precise chemical composition of humus," while King[31] writes, "The humus of soils so far as its chemical composition is concerned is not well understood."

Subscribing to these opinions, it was thought possible that the low results obtained with the heavy carbonate treatment might be attributed to chemical reaction between some humus constituent and ammonium carbonate during the contact period before filtration. The possibility of the increase of humus where long contact of carbonate with soil is had, as being attributable to formation of some compounds of higher volatile point than 100°C. through reaction of humus solution with the carbonate, was also considered. Accordingly, two filtrates of 450 c. c. each were obtained from each of two soils, 2723 and 2995, by straight filtration with suction. Humus was determined upon the straight filtrate from both soils and 22.5 grams of ammonium carbonate were added to the second filtrates. A slight flocculation occurred in each case, and this was filtered off and analyzed. The filtered precipitate from soil 2723 showed a SiO_2 content of .0140 grams and required 20 c. c. of a .4 normal solution of $KMnO_4$ for oxidation of its organic matter content, while .0100 gram of SiO_2 was found in the precipitate from the black soil and 22 c. c. of .4 normal $KMnO_4$ were required to oxidize the organic matter occluded in the flocculated clay precipitate. This proved conclusively that the heavy decrease in humus upon the use of large amounts of ammonium carbonate is not due to precipitation through chemical reaction, but must be associated with physical causes. Humus determinations made upon these two sets of solutions showed a slight decrease, within analytical error, in the humus of the clay soil where 25-gram carbonate treatment of the filtrate was made, but an average of five determinations against average of triplicates on the rich soil showed an appreciable increase in the humus obtained by the same treatment. In order to eliminate the possibility of variation in solutions from different ammonia extractions, a rich grassland soil, 3120 b, was used to obtain through straight filtration by suction a composite of 1800 c. c. Sextettes of determinations were made upon this well-mixed original composite solution and upon portions subjected to contact with 25 and 50-gram charges of ammonium carbonate per 500 c. c., the results being given in Table IX. These data warrant the conclusion that the increases of humus on long standing of soil in contact with large amounts of carbonate (Table I) are due to the extended solvent action of either ammonia or ammonium carbonate overcoming

the original occlusion effected by the soil mass. The analyses further justify the conclusion that no fixation of ammonium carbonate, chemical or mechanical, is effected by the humus solution after its separation from the soil.

TABLE IX—*Effect of large amounts of ammonium carbonate upon humus solution obtained by straight filtration*

Straight filtration	25 gm. Carb. per 500 c. c. added to filtrate	50 gm. Carb. per 500 c. c. added to filtrate	Straight filtration	25 gm. Carb. per 500 c. c. added to filtrate	50 gm. Carb. per 500 c. c. added to filtrate
Per cent humus	Per cent humus	Per cent humus	Per cent ash	Per cent ash	Per cent ash
5.95	6.11	5.98	1.16	1.16	1.13
6.01	6.13	5.97	1.12	1.19	1.12
6.01	6.08	5.98	1.12	1.14	1.18
5.92	6.07	6.09	1.16	1.09	1.14
5.95	....	6.04	1.13	....	1.09
5.98	6.10	6.03	1.14	1.15	1.10
Average 5.97	6.10	6.02	1.14	1.15	1.13

SOLVENT ACTION OF "AMMONIUM CARBONATE C. P."

The activity of ammonium carbonate upon organic matter was studied by causing contact of soil for 36 hours with distilled water, into which had been introduced 1, 2½, and 25-gram charges of ammonium carbonate per 500 c. c., and extracts secured by filtration with suction. In another set the soil was in contact with distilled water alone for 36 hours, after which period the three amounts of carbonate were added and filtration was accomplished upon complete solution of the salt. In this second set the dissolved carbonate was in contact with the soil less than one hour as contrasted with 36 hours in the first set. It required one hour to filter 500 c. c. of solution after 36-hour contact of soil with ammonium carbonate as compared with 9 minutes for a 500-c. c. filtrate when the filtration was accomplished within an hour after introduction of the salt. The water solutions of the carbonate used for 36-hour contact period were aspirated for an hour and a half to remove any free gases before introducing soil into the cylinders. The carbonate used in the case of immediate filtration after the addition of the salt was freed of free ammonia and CO_2 by heating to 50°C. in an electric oven. Free ammonia was detected in both soil solutions after the soil had stood in contact with the solution of 25 grams of carbonate for both 1-hour and 36-hour periods, but no trace was discernible by odor where but 1 and 2½ grams were used for either contact period. All solvent action shown in Table X should therefore be attributed to normal or acid carbonate of ammonia in the case of 1 and 2½-gram treatments. It should be noted,

however, that when the carbonate is used with ammonium hydrate, *theoretically* there is no acid carbonate present, the acid carbonate in the commercial salt being converted to the normal carbonate by the reaction $NH_4HCO_3+NH_4OH=(NH_4)_2CO_3+H_2O$. The commercial carbonate, which is a combination of ammonium acid carbonate and ammonium carbamate when brought into contact with water, reacts according to the equation $NH_4HCO_3.NH_4NH_2CO_2+H_2O=(NH_4)_2CO_3+NH_4HCO_3$. Unless ordinary C. P. carbonate has been purified by alcohol or treated with concentrated ammonia, resulting in the precipitation of the normal carbonate from the solution, there is of course considerable of the acid carbonate present in water solution. As previously stated in this paper, the two samples of Kahlbaum's C. P. ammonium carbonate and one of Mallinckrodt's were heavily charged with acid salt. Part of the solvent action shown in Tables X and XI is therefore probably attributable to the acid carbonate (see Table XII). The presence of this excess of acid carbonate should theoretically care for any ammonia liberated by absorption of the soil mass, but as previously stated there was a trace discernible by odor in the 25-gram treatment with distilled water at 20°C., though none was detected in the 1 and 2½-gram solutions.

The analyses of Tables X and XI emphasize the distinctive solvent action of ammonium carbonate, which in the smaller amounts dominates the occlusion, the reverse being the case with the large amount. The importance of the factor of time of contact of carbonate with soil is also plainly demonstrated. In the modification proposed, the amount of carbonate and time of contact are reduced to minima and if either influence exerts itself quantitatively, the two are so nearly identical under the conditions cited that no difference save lowering of ash and increased speed of filtration is discernible in comparative analyses. It is interesting to observe that in the 36-hour period the solvent action of 2½ grams of carbonate, the amount suggested by Rather, is 48 per cent of that exerted by the 4 per cent NH_3 in the loam soil and 68 per cent in the case of the virgin soil.

THE INFLUENCE OF PERIOD OF CONTACT UPON SOLVENT ACTION OF "C. P." COMMERCIAL AMMONIUM CARBONATE

The influence of time of contact of carbonate with soil was studied by securing distilled water extractions, contact periods being, immediate filtration, overnight, and two nights and a day. One, 2½ and 25-gram charges of the commercial carbonate of ammonia were used. The analyses are incorporated in Table XI.

TABLE X—*Solubility of humus in water solutions of "ammonium carbonate C. P."—contact of soil with water and various amounts of carbonate for 36 hours*

Treatment	Per cent humus								Per cent ash							
	Loam soil 2723				Virgin soil 2995				Loam soil				Virgin soil			
	A	B	C	Avg.	A	B	C	Avg.	A	B	C	Avg.	A	B	C	Avg.
H_2O alone	.18	.19	.20	.19	.32	.36	.31	.33	.12	.10	.13	.12	.14	.12	.15	.14
H_2O + 1 gm. Carb. . .	.36	.43	.44	.41	1.41	1.39	1.38	1.39	.07	.13	.08	.09	.13	.13	.14	.13
H_2O + 2½ gm. " . .	.66	.63	.58	.62	2.96	2.94	2.97	2.96	.10	.10	.10	.10	.24	.27	.27	.26
H_2O + 25 gm. " . .	.54	.55	.61	.57	1.63	1.63	1.64	1.63	.14	.13	.11	.13	.18	.20	.17	.18

TABLE XI—*Influence of time of contact of "C. P." ammonium carbonate with meadow soil*

Treatment	Immediate filtration				Overnight contact				36-hour contact				Immediate filtration				Overnight contact				36-hour contact			
	Per cent humus				Per cent humus				Per cent humus				Per cent ash				Per cent ash				Per cent ash			
	A	B	C	Avg.	A	B	C	Avg	A	B	C	Avg.	A	B	C	Avg.	A	B	C	Avg.	A	B	C	Avg
H_2O alone........	.09	.07	.09	.08	.29	.32	.28	.30	.32	.36	.31	.33	.06	.09	.11	.09	.09	.09	.09	.09	.12	.14	.15	.14
H_2O + 1 gm. Carb.	.53	.56	.58	.56	2.52	2.47	2.58	2.52	3.80	3.74	3.74	3.76	.06	.06	.07	.06	.17	.18	.25	.20	.13	.13	.14	.13
H_2O + 2½ gm. "	.67	.71	.68	.69	2.79	2.78	2.81	2.79	3.83	3.92	3.94	3.90	.11	.08	.11	.10	.17	.18	.19	.18	.38	.36	.36	.37
H_2O + 25 gm. "	.68	.71	.69	.69	1.70	1.65	1.65	1.67	2.59	2.66	2.68	2.64	.11	.10	.11	.11	.15	.16	.21	.17	.50	.29	.28	.36

REACTION BETWEEN ACID CARBONATE AND AMMONIUM HYDRATE

One sample of "ammonium carbonate C. P." used was found to contain 78.4 per cent acid carbonate and by difference, 21.6 per cent normal carbonate. Seventy-five grams of this carbonate were digested for 8 hours at room temperature with 500 c. c. of 4 per cent NH_3 solution, and of the 58.8 grams of acid carbonate in the charge 17.5 grams were still unconverted to the normal salt at the end of the digestion. Charges of 1, 2½ and 25 grams of the C. P. carbonate were then digested overnight and no precipitation of acid carbonate was obtained, after this treatment. The same amounts were then digested for two hours, the maximum time of contact in the modified filtration, and the 1-gram charge was apparently free of acid carbonate at the end of the 2-hour period, but neither the 2½ nor the 25-gram amount was entirely converted to the normal salt during that period. It would appear from this work that part of the flocculation in the 2½ and 25-gram treatments of the modified procedure is due to acid carbonate and that the final influence exerted in the Rather procedure is in the presence of only the normal salt.

The commercial "C. P." carbonate mixture was compared in its flocculating action upon red clay with that of pure acid carbonate and pure normal carbonate. The acid carbonate gave quicker flocculation, but on standing overnight the three salts appeared to give identical results.

Twelve-hour digestions of distilled water with 1, 2½ and 25-gram charges each of the "C. P." carbonate and laboratory-prepared acid carbonate and normal carbonate of ammonia were effected and the results given in Table XII. These analyses demonstrate that in the 12-hour period of the Rather treatment the physical effect and solvent action of the carbonate of ammonia are sufficiently marked to influence the determination.

TABLE XII—*Comparison of solvent action of original "C. P." ammonium carbonate and its content of normal and acid carbonates, with laboratory-made acid carbonate and normal carbonate, as measured by humus recovered in water solution after overnight contact. (No aspiration)*

Amount of carbonate	Original C. P. carbonate				Acid carbonate residue of original carbonate				Normal carbonate content of original carbonate by difference				Acid carbonate laboratory product				Normal carbonate laboratory product			
	Per cent humus				Per cent humus				Per cent humus				Per cent humus				Per cent humus			
	A	B	C	Avg.	A	B	C	Avg	A	B	C	Avg.	A	B	C	Avg.	A	B	C	Avg.
1 gram	2.52	2.47	2.58	2.52	1.13	1.17	1.15	1.15	1.31	1.37	1.34	1.34	2.38	2.58	2.69	2.55	2.44	2.45	2.42	2.43
2½ gram	2.79	2.78	2.81	2.79	2.09	2.01	2.09	2.06	.72	.70	.77	.73	2.57	2.62	2.62	2.60	3.05	3.04	3.07	3.05
25 gram	1.70	1.65	1.65	1.67	1.67	1.63	1.58	1.63	.03	.02	.07	.04	1.73	1.78	1.80	1.77	1.76	1.78	1.80	1.77
	Per cent ash				Per cent ash								Per cent ash				Per cent ash			
	A	B	C	Avg.	A	B	C	Avg.	Blank with distilled water				A	B	C	Avg.	A	B	C	Avg.
									Average per cent humus			Average per cent ash								
1 gram	.17	.25	.18	.20	.14	.14	.17	.15					.31	.21	.15	.22	.17	.16	.16	.16
2½ gram	.18	.19	.17	.18	.15	.18	.15	.16					.13	.12	.12	.12	.19	.21	.21	.20
25 gram	.15	.21	.16	.17	.10	.14	.21	.15	.30			.09	.16	.08	.09	.11	.21	.15	.15	.17

SPEED OF FILTRATION AS AFFECTED BY USE OF SAND

The clay loam soil, 2723, usually requires about 1 to 1½ hour of filtration after clear filtrate is obtained in order to secure 300-c. c. portions of filtrate. The influence of sea sand as affecting the filtration of this soil was tried, and it was found that 1 gram of ammonium carbonate and 25 grams of carbon-free sand added and mixed just before filtration gave a filtrate of 300 c. c. in 30 minutes. At the end of the 36-hour period of contact with ammonia, the carbonate and sea sand were added and the cylinder stoppered and inverted over the funnel. The cylinder was then quickly unstoppered and the filter filled; from 2 to 5 minutes permitted settling of the material in the filter and insured absolute clearness of the filtrate. The supernatant portion was then pipetted back into the cylinder, and when the surplus of solution in the filter bed was drawn through the filter, suction was released, the flask container washed, and suction again applied for a minute. The solution in the cylinder was then transferred to the filtrate. Ten grams of red clay from a sub-cellar digging were treated in this manner, and by straight filtration without sand or carbonate. One gram of carbonate and charges of 25 and 50 grams of sand gave absolutely clear filtrates in 3 minutes. At the end of two hours and a half approximately 300 c. c. of filtrates were obtained where the sand was added to the clay, while but 175 had been collected during the same time where 1 gram of carbonate was not supplemented by sand, and 36 hours were required to secure 300 c. c. of filtrate without carbonate or sand. The analyses of the red clay extraction by the different filtrations are given in Table XIII.

TABLE XIII—*Humus determinations upon red clay subsoil by modified procedure. Effect of ammonium carbonate and sand upon speed of filtration and percentage of ash*

Straight filtration		1 gm. $(NH_4)_2CO_3$ at filtration		1 gm. $(NH_4)_2CO_3$ 25 gm. quartz sand at filtration		1 gm. $(NH_4)_2CO_3$ 50 gm. quartz sand at filtration	
Per cent humus	Per cent ash	Per cent humus	Per cent ash	Per cent humus	Per cent ash	Per cent humus	Per cent ash
.14	1.27	.30	.61	.24	.08	.45	.14
.16	1.28	.36	.59	.23	.07	.46	.15
.11	1.18	.30	.52	.23	.09	.39	.13
Average .14	1.24	.32	.57	.23	.08	.43	.14

However, when the sand modification was tried quantitatively upon the two types of soil, 2723 and 2995, it was found to give widely divergent results, and the increase in speed obtained in the clay loam was exactly opposite to that of the black soil, where the retardation was appreciable. Analyses of the clay soil showed no effect upon the humus in the filtrate, but four digestions filtered with 1 gram of carbonate and 25 grams of sand gave decidedly lower results in every case as compared with four digestions filtered with 1 gram of carbonate and no sand. As previously stated, the black soil contained very little clay, but very large amounts of iron, probably in ferrous state originally, due to poor drainage. A gelatinous precipitate, apparently identical with the ordinary ammoniacal precipitations of iron hydrate in the cold, was characteristic of all the determinations upon the black soil, and the effect of this precipitate upon the speed of filtration was decidedly marked. The authors believe, therefore, that in comparative studies involving more than one soil the introduction of quartz sand into the mixture before filtration is not desirable, and certainly it should not be used without preliminary determinations upon a soil, where comparisons are made of different treatments of the same type of soil. Then, too, the additional analyses for blank and correction for the soluble matter of the sand increase the calculation.

The ash of the clay loam soils studied was less by the modification than the ash of either ammonia extracted or ignited sea sand.

A COMPARISON OF MODIFIED SMITH, RATHER, MOOERS-HAMPTON, AND MODIFIED PROCEDURES UPON LOAM AND VIRGIN SOILS

The results in Table XIV represent analyses by the different procedures involving the use of ammonium carbonate, as compared with the modified Smith procedure and the Mooers-Hampton modification. The very high ash and humus shown by the original Rather procedure upon the virgin soil is doubtless due to the presence of a very large amount of iron, which is not removed by the Rather procedure, though there is an appreciable elimination of the ferric portion of the ash easily discernible to the eye in all the methods using filtration with suction.

TABLE XIV—*Comparison of modified Smith procedure with Rather and Mooers-Hampton methods and the modification with the original 2½-gram carbonate and 1-gram carbonate treatments*

Soil	Modification of Smith method		Original Rather method		Mooers-Hampton method		Modified filtration 2½ gm. carbonate		Modified filtration 1 gm. carbonate	
	Per cent humus	Per cent ash	Per cent humus	Per cent ash	Per cent humus	Per cent ash	Per cent humus	Per cent ash	Per cent humus	Per cent ash
Loam	1.29	.53	1.13	.31	1.16	.90	1.03	.18	1.29	.29
	1.20	.53	1.14	.34	1.20	.90	1.05	.18	1.32	.32
	1.38	.62	1.04	.34	1.32	.77	1.17	.21	1.24	.27
Average	1.29	.56	1.09	.33	1.23	.86	1.09	.19	1.28	.29
Virgin	4.35	.53	4.98	1.21	4.31	.77	3.44	.33	4.45	.69
	4.28	.67	4.97	1.18	4.19	.94	3.49	.38	4.52	.70
	4.36	.81	4.95	1.19	4.17	1.11	3.93	.31	4.58	.70
Average	4.33	.67†	4.97	1.19*	4.22	.94†	3.62	.34†	4.52	.70†

* Heavily charged with ferric oxide.

† Charged with ferric oxide.

The high ash noted in the determination by the Rather procedure is not due to the presence of clay, but apparently to colloidal iron, which is not removed even by the additional manipulation suggested by Rather for Hawaiian soils [22]. Boiling for 5 minutes also failed to throw out the iron from the filtrate obtained by the Rather modification. Ammonium sulphide precipitated iron, but also considerable of organic matter, from the solution obtained by the Rather method. Carbon bisulphid eliminated iron without any apparent effect on the organic matter content of the ammonia solution.

In washing this soil with dilute HCl, large amounts of iron are removed and considerable of iron is obtained even with cold digestion with distilled water. The ash of the filtrate secured from this soil by the modified filtration with 1 gram of carbonate was about one-half of that of the Rather procedure, and showed a content of 44 per cent Fe_2O_3. It would appear eminently fair in the case of a very unusual soil of this kind, where there is practically no clay in the ash, to apply a correction of one-third of the ash as representing the conversion of $Fe_2(OH)_6$ to Fe_2O_3 during ignition.

NEED OF AN ACCURATE AND RAPID METHOD

The authors have failed to find record of an investigation of the official method which did not demonstrate the inefficiency of the procedure, due to the difficulty of the elimination of clay and hydrated iron from the filtrate. Since much of the foregoing data was obtained, the A. O. A. C. in 1913, without a dissenting voice, eliminated the former official method for humus from its approved methods, and there seemed to be unanimity of opinion among those present as to the inaccuracy of the former official procedure. It did not appear, however, to be intended that the importance of the determination of *ammonia-soluble organic matter* should be minimized, but the inefficiency of the official procedure was emphasized, and for this reason the faulty method was deprived of the official sanction of the Association. It would seem that the difficulty of removing clay from the ammoniacal solution is not surrounded by walls of impossibilities, and while it is conceded that the Association is amply justified in abandoning an inefficient and ineffective procedure, it were better that the task of perfecting a method be accomplished, rather than abandoned. It is probably true that the term *"humus"* has been used erroneously and without sufficient definiteness, and this fault may, to some extent, be remedied by the Association's action. In view of the large amount of work already started, wherein the ammonia-soluble organic matter has been used as a measure, relative, possibly, rather than absolute, it is to be hoped that there may be perfected for adoption by the A. O. A. C. a method meeting absolutely the requirements of the Association for the determination of *ammonia-soluble organic matter*, for certainly prestige should be accorded

an investigation based upon analytical data secured by a procedure bearing the stamp of approval of so conservative an official body. It would seem that the method would bear the same relation to the very important determination of total organic matter by combustion that acid digestion (1.115 HCl) bears to the determination of total mineral elements by fusion. The original Rather procedure was studied three years and twice recommended for adoption as official by the Referee, Dr. Fraps, but official sanction of the Association was not accorded. However, the principle of the Rather method is admirable, and with the reduction in the amount of carbonate and shortening of its period of contact with the soil, to eliminate the factor of occlusion, at the same time making filtration a feasible incident of laboratory routine, it would seem that any possible objections are removed. The Smith method, as modified by use of the disc filter with suction where speed is not a factor, can be utilized in working upon the soils investigated in this laboratory. While the work reported in this paper was done primarily because of the need of rapid determinations upon many different field treatments of a clay loam soil, the writer believes that in cases of soils such as reported by Kelly and McGeorge[15], with possibly slight modification, the method would give admirable results. It would appear that rapid and efficient filtration of a pure clay is about as severe a test as would ordinarily be encountered.

EFFECT OF CHANGE OF STRENGTH OF AMMONIA

By referring to Bulletin 46, Division of Chemistry, page 42, and Bulletin 107 (Revised), Bureau of Chemistry, page 19, it will be seen that the original designation of strength of ammonium hydrate as "4 per cent ammonia" has been in some manner, through error, changed to read "4 per cent ammonium hydrate," which is less than 50 per cent of the strength originally designated. In recent work of referees on soils the term "4 per cent ammonium hydrate" has been used, but the calculation given in terms of acid equivalence has been for 4 per cent ammonia.

Because of this discrepancy, 4 per cent ammonium hydrate was used in a comparison between the Mooers-Hampton method and the modified filtration procedure, with and without ammonium carbonate on clay soils. There was a marked difference between the speed of filtration of the two strengths. It required 24 hours to filter 400 c. c. of the dilute solution, while but 2 hours, as a maximum, were required for the stronger solution. Furthermore, the straight filtration checked very closely with the carbonate treatment, and triplicate digestions of six soils gave concordant filtrates, but both methods of filtration gave decidedly lower results than the Mooers-Hampton method. In the soils studied there seems to be occlusion effected by the use of the weak solution which is not evident in the use of the greater strength. *It is emphasized that all results reported by the authors were secured by using 4 per cent NH_3 solution.*

MODIFICATION IN DETAIL

The modification in detail, as used with splendid agreement and adopted in this laboratory, is as follows: 10 grams of the average soil are in contact with about 150 c. c. of 1 per cent HCl for 2 hours with frequent stirring. Four hours contact is sometimes required with soils rich in carbonates. Measured in terms of CO_2 evolved, the effect of this dilute acid on the organic matter of a fertile soil, when in contact even overnight, is negligible. The soil is agitated at the end of 2 hours and thrown upon a 9-cm 597 S. & S. filter,which has previously been moistened with dilute HCl and closely drawn to the perforated disc of a 10-cm Buchner funnel by suction. *The filter should not reach quite to the side of the funnel and should not extend up the side.* After the passage of the acid which has been in contact with the soil, two washings of about 100 c. c. each are allowed to run through and then a 2½-liter bottle with a bevel-edged glass tube projecting about ½ inch out of the stopper is filled with acid, inverted and suspended above the Buchner to maintain a constant level feed. (See Fig 1.). Speed of filtration, which should not be too rapid, is regulated by the amount of suction applied. When free of lime, the soil is washed free of acid by the same procedure. Racks to hold 20 inverted bottles, two sets of 10 each, are used in this laboratory. (See front-piece illustration). The large surface for filtration and the very thin soil layer give much quicker and more satisfactory results than the old procedure of using a Gooch filter. The Hagerstown silty clay loam of the Pennsylvania Station plots containing over 1 per cent total CaO has been entirely freed of lime without difficulty by this manipulation. The filter, after excess of moisture is removed by suction, or after drying, is removed from the Buchner funnel and placed against the side of a 6 or 8-inch cone-shaped funnel leading into the ammonia digestion cylinder. Any particles of soil remaining in the Buchner are brushed into the funnel and the mass is washed from the paper into the cylinder with 4 per cent ammonia solution. Gentle rubbing of the filter surface, squeezing the filter dry after washing, will cause removal of all silt and clay. Make up to 500 c. c., incline the cylinder to give greatest possible surface exposure, and allow to stand 36 hours (two nights and a day), with agitation each hour during the working day. In this laboratory we have a definite procedure by which we transfer all soils to the cylinder in contact with ammonia the last part of the working day and agitate during the day following, filtration being made the morning thereafter. At the end of the period of contact with ammonia, introduce 1 gram C. P. ammonium carbonate into the cylinder, invert several times to dissolve, and mix. After standing 10 to 15 minutes, pour about 50 c. c. of the agitated mixture on two 597 S. & S. filters, which have previously been moistened with 4 per cent NH_3 solution, and tightly drawn to the disc by 3 to 5 inches vacuum. The writers prefer the 10-cm Buchner for washing free of lime,

but the 25-cm size gives much more rapid and efficient filtration than the smaller size in filtering the 4 per cent NH_3 solution. Seventy-five to 100 filtrations a day can be effected by two men using a battery of 10 filters of this size. As in the acid washing, the filter should not extend quite to the walls of the funnel. The passage of but 15 to 25 c. c. through the filter will result in a perfectly clear filtrate. When the filtrate becomes clear, discard the first portion or return to main solution. Re-connect the filter flask after cleansing and apply vacuum, which affords filtrates of 300 c. c. in 30 to 90 minutes. The bell jar filtering device may be substituted for the Erlenmeyer filtering flask. Keep the Buchners covered with watch glasses during filtration. The aliquots of 100 c. c. are evaporated, weighed and ignited in the usual way. The only difficulty presenting itself in the use of this method for a large number of simultaneous determinations is the question of sufficient suction. The ordinary water filter may give sufficient suction for one or two determinations, but not for a battery of 10 or more. In this laboratory we have a vacuum system whereby we are able to maintain as high as 28 inches vacuum by means of a rotary pump driven by a 2-horsepower motor.

SUMMARY AND CONCLUSIONS

Essentially the modification proposed by the authors consists of reducing the 2½-gram ammonium carbonate charge of the Rather procedure to 1 gram and filtering the entire mixture immediately after adding the carbonate, using the Buchner funnel with suction (Fig. 1).

The efficiency of the Brown-MacIntire[19a] device for elimination of calcium and magnesium prior to digestion with ammonia is emphasized.

The Buchner funnel with suction was used effectively for filtration of humus extraction with or without the addition of ammonium carbonate.

The soil itself acting as a filter bed is the best filtering medium. The entire charge of soil used as a filter bed gave the most satisfactory results.

Composite filtrates from 6 soils showed no difference between the humus content of the first and second portions of the filtrations.

Sand added to the soil at time of filtration increases speed of filtration, but is not unqualifiedly recommended as being uniformly desirable.

The modified procedure increases fivefold the speed of the Smith method and gives less ash than the Mooers-Hampton, Smith or the original Rather procedure.

No sediment was found after six months in the solutions obtained by the modification given.

The humus percentages of the ammoniacal solutions containing carbonate, change upon standing in contact with soil.

One gram of carbonate in the modification given apparently affords as efficient filtration as 2½ grams, but by the Rather procedure 1 gram is not sufficient for the soils under investigation.

There is decided occlusion resulting from the use of more than 1 gram of carbonate per 500 c. c. in both the Rather method and the modification, the occlusion being greatest with the largest amount of carbonate used.

Analyses show no occlusion of humus with 1-gram treatment and immediate filtration, the increase in speed of filtration and lessening of ash being the only perceptible effects.

Long periods of contact of soil with ammoniacal solution of carbonate lessened the tendency toward the low results effected by the use of carbonate. (See Table I).

Two nights and a day's contact of soil with ammonia is sufficient and is to be preferred to a shorter period.

Because of the two distinctly opposite influences of ammonium carbonate, and occlusion effected, the period of contact of soil with carbonate is an important factor, and in the modification is reduced to the minimum.

The decrease in humus resulting from the addition of carbonate can not be attributed to lessening of alkalinity.

There is no *chemical* precipitation from the humus solution effected by the addition of ammonium carbonate.

There is no fixation of carbonate, chemical or mechanical, in the solution free from contact with the soil.

The physical effects (occlusion) of 25-gram charges of normal carbonate and acid carbonate of ammonia and mixtures of the two salts are greater than their solvent action in both water and ammonia solutions, the reverse being the case with the smaller treatments.

Twelve-hour contact with 4 per cent ammonia converted all acid carbonate in the three amounts used to normal carbonate, but 2-hour contact does not convert all of the bicarbonate in 2½ and 25-gram charges of the salt.

Pure clay may be easily filtered *immediately* by the modified procedure.

Results by the Smith and Mooers-Hampton methods are more in accord with those obtained by the 1-gram modification than with those obtained by the original Rather procedure.

The solution of the black meadow soil was not freed from excess of iron by the later modification suggested by Rather[32]. Ammonium sulphid removed both iron and organic matter from ammonia solution. Carbon bisulphid eliminated iron without any apparent effect on the organic matter of the ammonia solution. In such unusual cases where the ash is shown to be due to $Fe_2(OH)_6$ instead of to clay the application of a correction of 33 per cent is suggested.

The ash obtained by the 1-gram modification from the clay soils studied was less than that of either ammonia digested or ignited sea sand.

Repeated *digestions* and filtrations by the 1-gram modification upon the same soils have given solutions practically identical in analysis.

It is emphasized that the original official method directs the use of 4 per cent NH_3 instead of 4 per cent NH_4OH, as is erroneously given in Bulletin 107, Bu, of Chem. (Revised).

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Agricultural Experiment Station

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FEEDING BEEF CATTLE

BY

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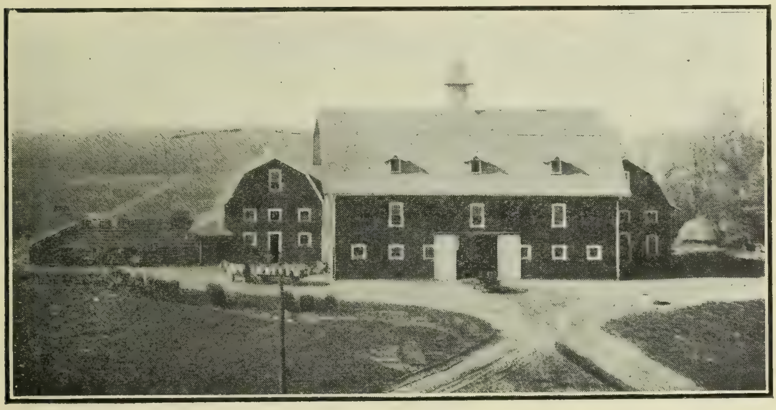

LIVE STOCK BARNS, WEST TENNESSEE EXPERIMENT STATION

The animals used in the experiment were under the supervision of S. A. Robert, Supt., West Tenn. Exp. Sta., and the data were compiled by C. A. Willson.

KNOXVILLE, TENNESSEE

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OF THE UNIVERSITY OF TENNESSEE

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The Experiment Station building, containing the offices and laboratories, and the plant house and part of the Horticultural Department, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy building, etc., are located one mile west of the University on the Kingston Pike. The fruit farm is adjacent to the Industrial School and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

FEEDING BEEF CATTLE

Conclusions from Four Years of Experiments at the West Tennessee Experiment Station

SUMMARY

1. Medium cottonseed-meal rations, in amounts increasing from 5 to 7 pounds per head per day, are equally as efficient as high cottonseed-meal rations, in amounts increasing from 7 to 9 pounds, from the standpoint of gains. The same rate of gain was obtained at a much less cost.—p. 91.

2. The average daily gain where steers were fed in amounts increasing from 3 to 5 pounds of cottonseed meal per head per day was 1.52 pounds; where steers were fed in amounts increasing from 5 to 7 pounds the daily gain was 1.75 pounds; and where they were fed in amounts increasing from 7 to 9 pounds the daily gain was 1.72 pounds.—p. 90-92.

3. The average cost of a pound gain with lots receiving amounts increasing from 3 to 5 pounds of cottonseed meal per head per day was 8.5 cents; with lots receiving amounts increasing from 5 to 7 pounds, 8.5 cents; and with lots receiving amounts increasing from 7 to 9 pounds, 12.1 cents.—p. 95.

4. Feeders are not warranted in the use of cottonseed meal to the extent of 7 to 9 pounds per head per day except for short feeding periods of 30 to 50 days.—p. 95.

5. High cottonseed-meal rations were more efficient when fed with hulls than when fed with silage. High meal and hulls were not, however, as efficient as medium meal and hulls, or medium meal and silage.—p. 96.

6. Silage proved much more efficient than hulls. The average gain with silage and cottonseed meal was 154.9 pounds; with hulls and cottonseed meal, 144.1 pounds; and with a combination of silage, hulls and cottonseed meal, 171.7 pounds.—p. 99.

7. Silage made 7.3 per cent more gain than hulls, at 27.7 per cent less cost than cottonseed hulls.—p. 99.

8. The average cost of a pound gain where cottonseed hulls were fed was 11.3 cents, and where silage was fed, 8.2 cents.—p. 102.

9. Where silage may be had, only a small amount of hulls should be fed.—p. 102.

10. Allowing that the manure offsets the cost of labor, and that the steers are fed on a $1.50 margin and sell for $7.00 per hundredweight, silage was worth $7.65 per ton and cottonseed hulls were worth $13.78 per ton. Had there been but a dollar margin between the purchase and selling prices of steers only $9.57 would have been obtained for each ton of hulls fed.—p. 104, 105.

11. The average profit for steers receiving hulls was $7.28 and for steers receiving silage, $11.28. A much wider margin is needed when hulls are fed than when silage is fed.—p. 105.

12. In 1910, steers that were the result of one or more crosses of a beef breed made 39.2 pounds more gain than steers in which the dairy blood predominated. Beef-bred steers made 41.0 pounds more gain than scrub steers.—p. 106.

13. The average gain of steers of the best beef type, for two years, was 33.9 pounds higher than that of steers of the poorest type.—p. 107.

INTRODUCTION

FERTILITY IN FEEDS

The growing of beef cattle in the South has great possibilities because of the ease with which forage crops can be grown, and also because of the availability of cottonseed meal, which may be used with silage to finish cattle for the market. If more cottonseed meal were fed more cotton and corn could be produced.

Beef production in the South

The South is producing 59.0 per cent* of the world's cotton upon only 5.7 per cent of its total area and on only 9.0 per cent of its land in farms. Cotton is grown on only 21.2 per cent of the improved farm area of the South. Corn is grown on 22.9 per cent of the improved farm area. Of the total farm area 42.5 per cent is improved, while 57.5 lies as yet unimproved. Furthermore, of the 55.9 per cent of improved land not used for cotton or corn production, many thousands of acres lie idle each year. If these thousands of acres not used each year for corn or cotton production were sown to Bermuda grass and Japan clover and grazed by cattle there would be an added return of millions of dollars to the Southern farmer. Live stock production could likewise utilize in a measure the 57.5 per cent of non-improved lands. It is difficult to conceive what might be the returns to the Southern farmer if all of the waste lands of the South were utilized in live stock production. Land fertility would be maintained and increased, more cotton per acre could be grown, and greater prosperity would prevail. The effect of rotation of crops and foraging upon the land has been shown in a practical way by many farmers, and has been proven by experiments. The Arkansas Station, in Bulletin 68, has shown that there was an increased production of cotton the following year where cowpeas were sown in corn and the stalks and cowpeas grazed in the usual manner after the corn was gathered. There was an increase of 626.5 pounds of seed cotton as compared with the production of another equal area of ground where corn alone was grown and harvested and the stalks unforaged.

*Based on production of 1909.

Loss of fertility from Southern farms through cottonseed removed

Live stock farming maintains soil fertility and improves the physical condition of the soil through the return of organic matter to it. The return to the land of feeding materials such as corn stalks, grass, hay, corn, hulls, and cottonseed meal in the form of manure would mean increased soil fertility and thus increased crop production. Without stock these materials are largely wasted. Coulter notes that "In 1850 cottonseed was treated as garbage and dumped on the waste heap. Twenty years later it was looked upon as a valuable fertilizer; by 1880 the cottonseed was found to be a nutritious cattle-feed, and by 1890 cottonseed oil was commencing to be used as a substitute for olive oil, and is now a human food." The cottonseed product of the South is now worth from $150,000,000 to $200,000,000 each year. Sixty years ago laws were passed making it a punishable offense for cotton ginners to leave cottonseed lying around the gin to rot, and equally punishable to dump these seed with linters attached into streams. Not more than three-fourths of the cottonseed is yet used to the best advantage. Millions of dollars worth of fertility is removed from the Southern farms each year. During the year 1909 over $53,000,000 worth of fertility was removed from Southern farms in the form of cottonseed, of which but a small portion was returned. Twenty-five per cent of the meal manufactured is exported, and of the remaining amount not more than 15 per cent is fed in the South. In 1909 the value of the fertility exported to other countries from the South in the form of cottonseed meal and cottonseed was over $18,000,000. The loss in fertility each year from the Southern farms from cottonseed alone that is sold is over $44,000,000. It is true that a large amount of this loss is being replaced each year with fertilizer purchased, but it could be much more economically replaced by feeding the cottonseed meal to live stock. There was produced in 1910, in Tennessee, 132,278 tons of cottonseed meal, which, had it all been fed in this State, would have returned more than $1,200,000 worth of fertility to the farms of the State.

Fertility lost through various crops

Before determining the profits from any crop produced on the farm, the loss in fertility to the land producing the crop should be estimated. Too often in farm practice this factor is not reckoned, and hence it is often said that farms do not produce the crops they did many years ago. Especially is this true of farms where all grains and hays produced are marketed as such instead of being manufactured into milk, beef, pork or mutton. The farmer who produces beef with the crops grown upon the farm may not from year to year obtain more than market prices for the grains fed; but the return of fertility to the farm means increased production, and thereby come his profits. The factor of lost fertility through the selling of crops such as grain, hay, cottonseed, etc., from the farm is too often dis-

regarded. Table I shows the value per ton of the fertilizing constituents of some of the common products sold from the farm.

TABLE I—*Manurial value of farm products*

Feed	Amount fertilizing materials per ton*			Value fertilizing materials per ton†			Total value per ton
	Nitrogen	Phosphoric acid	Potash	Nitrogen	Phosphoric acid	Potash	
	Lbs.	Lbs.	Lbs.				
Meadow hay	20.4	8.2	26.4	$ 4.08	$ .41	$1.32	$ 5.81
Clover hay	40.1	11.2	36.6	8.03	.56	1.83	10.42
Alfalfa hay	52.2	12.2	35.8	10.44	.61	1.79	12.84
Soy-bean hay	47.6	8.0	26.4	9.52	.40	1.32	11.24
Cowpea hay	28.6	10.4	29.4	5.72	.52	1.47	7.71
Wheat bran	49.2	54.6	28.6	9.83	2.73	1.43	13.99
Cottonseed meal	135.7	56.2	29.2	27.00	2.81	1.46	31.27
Wheat	37.5	15.8	10.6	7.50	.79	.53	8.82
Oats	36.4	12.4	8.8	7.28	.62	.44	8.34
Barley	39.7	15.4	9.0	7.93	.77	.45	9.15
Milk	10.2	3.4	3.0	2.04	.17	.15	2.36
Cheese	90.6	23.0	5.0	18.12	1.15	.25	19.52
Butter	5.7	.7	1.2	1.14	.03	.06	1.23
Live cattle	53.2	37.2	3.4	10.64	1.86	.17	12.67

* Data from Henry's "Feeds and Feeding."
† Based on the following prices: Nitrogen 20c, phosphoric acid 5c, and potash 5c.

If a ton of clover hay were returned to the soil as fertilizer it would have a value of $10.42, at average retail prices of fertilizers; a ton of wheat bran would be worth $13.99; a ton of cottonseed meal would be worth $31.27; and a ton of wheat would be worth $8.22. A bushel of wheat removes from the soil 26.5 cents worth of fertility, a bushel of oats 13.3 cents, a bushel of corn 23.4 cents, and a bushel of barley 22.0 cents.

Fertility returned when crops are fed to live stock

If these feeds are fed to live stock on land where it is desired that the manure be left, a large per cent of the fertility of the crop fed may be returned to the land. According to Kellner's research* with an ox that was putting on weight, but 6 per cent of the nitrogen fed in the food was retained. "Of the

*Hall's "Fertilizers and Manures," p. 192.

nitrogen supplied, 68.2 per cent was excreted in the urine, 25.4 per cent in the solids and about 6 per cent was retained by the animal." According to Warrington,* fattening cattle retain 2.3 per cent of the phosphoric acid and potash fed. It follows, then, that under good farm practice where grains and hays are fed on the land, 85 to 90 per cent of the fertilizing constituents of foods fed to farm animals may be recovered to the land. It is possible then, where grains and hays are fed on the land, to recover 22.5 cents worth of fertility for each bushel of wheat fed, 11.3 cents for each bushel of oats, 19.9 cents for each bushel of corn, 18.7 cents for each bushel of barley, $8.19 for each ton of clover hay, $4.49 for each ton of meadow hay, and $26.57 for each ton of cottonseed meal. Profits may nearly always be obtained from feeding live stock even when feeds are high; and if the manure made be properly cared for, profits may always be made with good live stock.

Fertility returned per steer

Assuming an average retail value of 20 cents for nitrogen and 5 cents for phosphoric acid and potash, there may be recovered with each fattening steer on feed three to six months, manure to the value of $9.00 to $16.00. According to Ohio Bulletin 183, there was recovered in the manure for each steer on feed for a period of six months, 68.1 pounds of nitrogen; 27.1 pounds of phosphoric acid and 36.1 pounds of potash. At average retail prices of the fertilizing constituents the manure would be worth $15.28 per steer. This value was obtained under stable conditions. Steers fed in the open would return a larger amount.

In Table II is shown the amount of fertility removed per acre in good crop production and also the manurial value of $10.00 worth of the feed when sold at market prices.

Fertility recovered with different methods of farming

Where large crops are produced and sold as such from the land, large losses of fertility take place. A 70-bushel crop of corn removes from the land $15.25 worth of fertility, and should always be charged as part of the expense in growing the crop before calculating the profits from the crop. If fed to steers in the open $12.96 worth of fertility may be recovered, and the corn sold at more than market price. All experimental work of the Station in feeding has been planned primarily with reference to soil fertility. Profits in farming are more dependent upon soil fertility and its maintenance than any other factor. Thousands of dollars are lost each year by wasteful systems of agriculture. Table III is given to show the approximate loss in fertility under four different methods of handling the corn crop.

*"Chemistry of the Farm," p. 214.

TABLE II—*Fertility in farm produce removed annually per acre**

Crop yield per acre	Market value	Fertilizing materials removed: Nitrogen	Phosphoric acid	Potash	Total retail value of fertility removed per acre	Manurial value of $10 worth †
		Lbs.	Lbs.	Lbs.		
70 bu. corn	$ .70 per bu.	70	12	13	$15.25	$3.06
60 bu. oats	.45 per bu.	40	7	10	8.85	3.23
25 bu. wheat	1.00 per bu.	36	6	7	7.85	3.84
25 bu. soy beans	2.00 per bu.	80	13	24	17.85	3.57
1000 lbs. cottonseed	.25 per bu.	63	11	19	14.10	9.65
2 tons timothy hay	18.00 per ton	48	6	47	12.25	3.40
2 tons clover hay	15.00 per ton	80	10	60	19.50	6.49
4 tons alfalfa hay	20.00 per ton	200	18	96	45.65	5.70
2 tons cowpea hay	15.00 per ton	87	9	65	21.10	7.03
200 bu. potatoes	.50 per bu.	42	9	60	11.85	1.19

*Composition based upon data from Hopkins' "Soil Fertility and Permanent Agriculture," p. 154.

† Based on same prices as in Table I.

TABLE III—*Losses in fertility from an acre under four methods of handling corn*

Method of handling crop	Fertilizing materials lost: Nitrogen	Phosphoric acid	Potash	Value of fertility lost
	Lbs.	Lbs.	Lbs.	
I—Corn 50 bu., 1.5 ton stover, all sold	74	10	34	$17.00
II—Corn 50 bu., 1.5 ton stover, corn sold and stalks burned	74	7	8	15.55
III—Corn 50 bu., 1.5 ton stover, corn sold, stalks plowed under	50	7	8	10.75
IV—Corn 50 bu., 1.5 ton stover, all fed to live stock	11	2	5	2.55

It is shown by Table III that if the same price is obtained for corn in each case there is $14.45 more profit per acre with Method IV than with Method I, or, $13.00 more for Method IV than for Method II. There is a loss per acre of $4.80 where the stalks are burned as compared with that where they are plowed under. Live stock farming means permanency in agriculture, increased fertility, and larger crop production. W. J. Spillman, of the U. S. Department of Agriculture, in Farmers' Bulletin 406, says, "The effect of live stock on the fertility of the soil needs no demonstration. It is well known to every intelligent farmer. Up to the present time, at least, no system of agriculture has been permanently profitable without the use of domestic animals as a means of maintaining the productiveness of the soil." Live stock farming gives the greatest ultimate returns per acre because of a minimum loss in fertility.

LOW, MEDIUM, HIGH COTTONSEED MEAL

Number of steers fed and object of the experiment

During the past four years the Tennessee Experiment Station has had on experiment 625 steers, 482 of which have been fed at the West Tennessee Experiment Station, at Jackson. These steers have been divided into a total of 46 groups, and extensive experiments made with feeds common to Tennessee and the South. In all experiments the basis of the ration has been silage and cottonseed meal. The object of these experiments has been to determine the most economical proportions of cottonseed meal in the ration and also the comparative values of hulls and silage for cattle in Tennessee. In all experiments emphasis has been given to soil fertility. During the winters of 1910-11, and 1911-12, and 1912-13, 357 head of steers were fed in the open, with the result that there has been the maximum conservation of the fertilizing elements in the manure produced.

A description was written of each steer on experiment and individual gains and weights were recorded in order that the influence of type and breeding on gains produced might be noted.

Rations fed

The rations fed in these experiments may be divided into two groups, as follows:

Group I. Medium vs. high or low amounts of cottonseed meal.

Group II. Combination of silage and cottonseed hulls vs. silage or cottonseed hulls.

Tables IV and V show the ration fed each year for each group of experiments.

TABLE IV—*Low, medium, and high cottonseed-meal rations*
Group I experiments

LOW COTTONSEED-MEAL RATIONS

Lot No.	Year	No. of steers	Ration*
5	1909	21	Silage, 3, 4, 5 lbs. cottonseed meal†
8	1910	8	Silage, 3, 4 5 lbs. cottonseed meal.
3	1911	8	Silage, 3, 4, 5 lbs. cottonseed meal.
11	1911	8	Silage, 3, 4, 5 lbs. cottonseed meal.
12	1911	13	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal.
5	1911	8	Silage 1st 45 days, 7, 8, 9 lbs. cottonseed meal last 45 days, 15 day periods.
1	1912	8	Silage, 3, 4, 5 lbs. cottonseed meal.
4	1912	8	Cottonseed hulls, 3, 4 ,5 lbs. cottonseed meal.

MEDIUM COTTONSEED-MEAL RATIONS

Lot No.	Year	No. of steers	Ration
1	1909.	16	Silage, 5, 6, 7 lbs. cottonseed meal.
3, 4	1910	8	Silage, 5, 6, 7 lbs. cottonseed meal.
2	1911	8	Silage, 4, 5, 6 lbs. cottonseed meal.
2	1912	8	Silage, 5, 6, 7 lbs. cottonseed meal.
5	1912	8	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal.

HIGH COTTONSEED-MEAL RATIONS

Lot No.	Year	No. of steers	Ration
7	1910	8	Silage, 7, 8, 9 lbs. cottonseed meal.
4	1911	8	Silage, 7, 8, 9 lbs. cottonseed meal.
13	1911	13	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal.
3	1912	8	Silage, 7, 8, 9 lbs. cottonseed meal.
6	1912	8	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal.

* In all rations the rough feed was fed according to the appetite of the steers unless otherwise stated.

† Represents the increase of grain from one period to the next; e. g., 3 lbs. first 30 days, 4 lbs. second 30 days, and 5 lbs. third 30 days.

TABLE V—*Silage and cottonseed-hull rations*
Group II experiments

SILAGE RATIONS

Lot No.	Year	No. of steers	Ration
1	1909	16	Silage, 5, 6, 7 lbs. cottonseed meal
3,4	1910	8	Silage, 5, 6, 7 lbs cottonseed meal
8	1910	8	Silage, 3, 4, 5 lbs. cottonseed meal
2	1911	8	Silage, 4, 5, 6 lbs. cottonseed meal
11	1911	8	Silage, 3, 4, 5 lbs. cottonseed meal
1	1912	8	Silage, 3, 4, 5, lbs. cottonseed meal
2	1912	8	Silage, 5, 6, 7 lbs. cottonseed meal
3	1912	8	Silage, 7, 8, 9 lbs. cottonseed meal

COTTONSEED-HULL RATIONS

Lot No.	Year	No. of steers	Ration
3	1909	16	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal
5, 6	1910	8	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal
1	1911	8	Cottonseed hulls, 4, 5, 6 lbs. cottonseed meal
12	1911	13	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal
13	1911	13	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal
4	1912	8	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal
5	1912	8	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal
6	1912	8	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal

COMBINATION SILAGE AND COTTONSEED HULLS

Lot No.	Year	No. of steers	Ration
2	1909	16	Silage, 6 lbs. hulls, 5, 6, 7 lbs. cottonseed meal
15	1910	8	Silage, 10 lbs. hulls, 4, 5, 6 lbs. cottonseed meal
7	1912	8	Silage, 6 lbs. hulls, 5, 6, 7 lbs. cottonseed meal

Increasing cottonseed meal

Cottonseed meal offers opportunity for extensive use in the South as one of the chief concentrates in the steer's ration. Even medium to large amounts of meal may be fed for short periods without detrimental effect. No detrimental effect was noticed in any of the groups fed cottonseed meal, even though the amount of cottonseed meal was increased toward the latter part of the finishing period. In order to

secure steady and increased gains toward the latter part of the finishing period the cottonseed-meal ration was increased in spite of the fact that the ration becomes narrower. In all the rations fed the protein supply was, therefore, increased toward the latter part of the fattening period through the increase of cottonseed meal.

Valuation of feeds used

Not much stress should be laid upon the valuation of feeds in experimental feeding, owing to the variations that occur in the prices of feeding stuffs from year to year and in different localities. The chief emphasis should be placed upon comparative gains produced and the feed required to produce them. However, for the sake of comparing costs and financial returns during the past four years, average market valuations were assigned to the feeds used. The following valuations were used:

Corn silage	$ 3.00 per ton
Cottonseed hulls	8.00 per ton
Cottonseed meal	25.00 per ton
Corn and cob meal	21.42 per ton

Steers on feed, West Tennessee Experiment Station

Description of yards and feed lots

During the first two years of the experiments, part of the steers were kept in the barn and part were fed in the open. Lots 1, 2, and 3, in 1909, and Lots 3, 4, 5, 6, 7, and 8, in 1910, were fed in open sheds. Lots 4 and 5, in 1909, and Lot 15, in 1910, were fed in the open. Where steers were fed in the open temporary fences and lanes were made with four strands of wire. Enclosures were made on the poorer parts of the farm, containing from one-half to three-fourths of an acre for each group, according to the number of steers to be enclosed, and feed racks and water were provided for each lot. The land in 1909, previous to being fed on, was soy-bean land, in 1910

corn land, and in 1911 soy-bean land. Cattle receiving a full feed did not suffer from cold or exposure and were comfortable so long as there were dry sleeping places. By a rotation of the feed troughs the manure was evenly distributed over each enclosure. All liquid manure was saved by its immediate absorption by the ground, and there was the minimum loss of both solid and liquid manure. In the spring the excess of manure was hauled to adjoining areas, and there was, therefore, the minimum labor required in handling the manure—no stables or pens to clean and the minimum of manure to haul. Three-fourths-inch piping was used to conduct water to each lot. The original cost of this piping was 3 cents per foot. The cost of laying each year was but little. The piping was laid in a ditch made by running twice with a plow. Three men in one day put in and covered from 12 to 18 inches deep one-fourth of a mile of piping. The ground was thoroughly tramped during wet weather, but there was no ill effect. On the contrary, owing to the fact that the manure tramped into the soil put organic matter there, the land was made better than before. No detrimental effect to the soil of Madison County was noticed when cattle were fed on small areas. The ground was broken at once after the steers were removed. Generally cattle fed in the open should be fed on pasture or meadow land. The feed racks should be moved often to give more comfortable feeding quarters and better distribution of manure. The feed racks were therefore all made small.

Description of steers used

The majority of the steers used in these experiments were purchased locally. Some of them were inferior in breeding, but have been valuable in showing the effect of breeding and type upon the gains produced. Two-year-old steers were used. At the beginning of each season's experiments the steers were divided as far as possible into groups of equal condition and quality. Each steer's number was suspended by a rope from the neck as a means of identification and a description of each was made with regard to breed, type, color, and distinguishing characteristics.

Weighing

The steers were weighed individually in the forenoon for three consecutive mornings at the beginning and end of each experiment, and the averages were used for the initial and final weights. Three-day weighings as well were made at the end of each 30 days.

Method of feeding

Two feedings per day were made, beginning at 7:00 a. m. and 3:00 p. m. Roughage feeds were tied in canvas sheets, and silage or hulls for each lot was put into large baskets. Grain feeds for each group were thoroughly mixed with the silage or hulls, after it was put into the rack. The cottonseed meal was always well mixed with the silage portion of the ration to insure each steer's getting his allotted portion of the meal.

Low, medium, high cottonseed meal

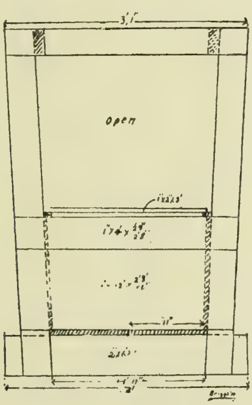
Cottonseed meal, because of its abundance in the South, should form one of the chief concentrated feeds for fattening or wintering steers; but as yet the limit to which it should, or may, be fed has not been determined. During the past four years this Station has fed cottonseed meal, in amounts varying from 3 to 10 pounds, to 221 steers. In all rations except six, corn silage has served as the basal ration. Table VI shows the results of low amounts of cottonseed meal.

TABLE VI—*Gains of steers fed low cottonseed-meal rations*

Lot No.	Year	No. of steers	Ration	Average initial weight	Average final weight	Average gain per steer: 1st 30 days	Average gain per steer: 2nd 30 days	Average gain per steer: 3rd 30 days	Average total gain per steer	Average daily gain per steer
				Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
5	1909	21	Silage, 3, 4, 5 lbs. cottonseed meal	746.5	962.1	106.1	39.8	69.7	215.6	2.40
8	1910	8	Silage, 3, 4, 5 lbs. cottonseed meal	926.1	1070.9	61.6	49.0	34.1	144.7	1.61
3	1911	8	Silage, 3, 4, 5 lbs. cottonseed meal	831.5	934.4	50.1	33.1	19.6	102.9	1.14
11	1911	8	Silage, 3, 4, 5 lbs. cottonseed meal	733.1	885.7	38.4	46.4	67.9	152.6	1.70
12	1911	13	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal	769.2	886.7	48.4	22.4	46.7	117.5	1.31
5	1911	8	Silage, no meal 1st. 45 da. silage, 7, 8, 9 lbs. 2nd 45 da.	795.4	897.5	26.7	35.3	40.1	102.1	1.13
1	1912	8	Silage, 3, 4, 5 lbs. cottonseed meal	1088.5	1254.1	55.9	48.5	61.2	165.6	1.84
4	1912	8	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal	1107.4	1204.2	46.0	29.9	21.0	96.9	1.07
Total		82	Average	874.6	1011.9	54.2	38.1	45.0	137.2	1.52

TABLE VII—*Gains of steers fed medium cottonseed-meal rations*

Lot No.	Year	No. of steers	Ration	Average initial weight	Average final weight	Average gain per steer			Average total gain per steer	Average daily gain per steer
						1st 30 days	2nd 30 days	3rd 30 days		
				Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1	1909	16	Silage, 5, 6, 7 lbs. cottonseed meal	841.9	1013.0	75.6	58.0	37.5	171.1	1.90
3, 4	1010	8	Silage, 5, 6, 7 lbs. cottonseed meal	957.0	1129.7	66.0	47.6	59.1	172.7	1.92
2	1911	8	Silage, 4, 5, 6, lbs. cottonseed meal	799.8	928.8	59.8	37.5	31.7	129.0	1.43
2	1912	8	Silage, 5, 6, 7 lbs. cottonseed meal	1115.2	1272.1	59.8	40.1	57.0	156.9	1.74
5	1912	8	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	1091.1	1257.5	74.2	55.4	36.8	166.4	1.85
7	1912	8	Silage, 6 lbs. hulls, 5, 6, 7 lbs. cottonseed meal	1116.4	1266.6	52.5	46.5	51.3	150.3	1.67
Total		56	Average	986.9	1144.6	64.7	47.5	45.4	157.7	1.75



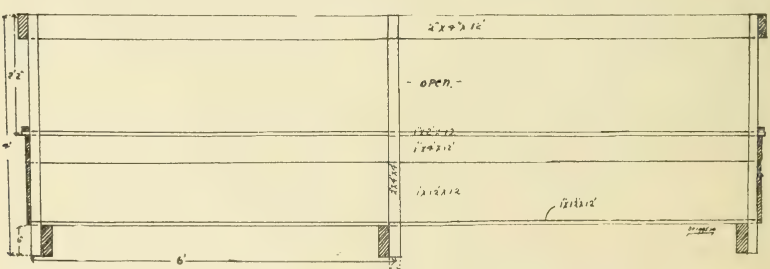
END VIEW OF TROUGH USED IN FEEDING STEERS

Amounts of cottonseed meal to feed

It is clearly shown from Tables VI, VII, and VIII that medium cottonseed-meal rations, of 5 to 7 pounds, are equally as efficient as high cottonseed-meal rations, of 7 to 9 pounds, from the standpoint of gains. The same rate of gain was obtained at a much less cost. Medium meal rations, of from 5 to 7 pounds, made better gains than low meal rations, of from 3 to 5 pounds. According to

TABLE VIII—*Gains of steers fed high cottonseed-meal rations*

Lot No.	Year	No. of steers	Ration	Average initial weight	Average final weight	Average gain per steer			Average total gain per steer	Average daily gain per steer
						1st 30 days	2nd 30 days	3rd 30 days		
				Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
7	1910	8	Silage, 7, 8, 9 lbs. cottonseed meal	924.4	1088.1	50.1	52.0	61.6	163.7	1.82
4	1911	8	Silage, 7, 8, 9 lbs. cottonseed meal	812.0	936.0	53.0	21.4	49.6	124.0	1.38
13	1911	13	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal	776.0	906.0	63.2	16.2	50.6	130.0	1.44
3	1912	8	Silage, 7, 8, 9 lbs. cottonseed meal	1102.0	1261.4	62.4	35.5	61.5	159.4	1.77
6	1912	8	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal	1094.6	1292.5	83.9	56.2	57.8	197.9	2.19
Total		45	Average	941.8	1096.8	62.5	36.3	56.2	155.0	1.72



SIDE VIEW OF TROUGH USED IN FEEDING STEERS

these experiments feeders are not justified in feeding cottonseed meal in as large quantities as 7 to 10 pounds, except where steers are on feed a very short time. Equally as good gains may be made with 5 to 7 pounds per head per day and at less cost. For short feeding periods, 30 to 50 days, larger amounts of cottonseed meal may be used with quite satisfactory results, but for longer feeding periods the gains diminish. This fact was especially brought out in Lot 5, year 1911, in which the steers were fed silage for 45 days and then fed 7, 8 and 9 pounds of cottonseed meal in periods of 15 days. The average

gain per head for the first 45 days was 28.2 pounds, or .63 pounds per day; while the gain for the last 45 days was 74.0 pounds, or 1.64 pounds per day. The total gain produced was not, however, greater than where 3, 4 and 5 pounds of cottonseed meal were fed in periods of 30 days, although the amount of meal fed was the same. Comparisons by years show practically the same results.

How to feed cottonseed meal

Where cottonseed meal is abundant and cheap, and where silage makes up the remainder of the ration, it appears that the greatest total gains may be made where 4 or 5 pounds of cottonseed meal are fed the first 30 days, 5 or 6 pounds the second 30 days, and 6 or 7 pounds the third 30 days. Care should always be taken in getting the steers on a full feed of cottonseed meal. Ten to 15 days should be taken, with slight increase each day, to get the steers on a feed of 5 pounds per head per day. At no time during the experiments was there any trouble that may follow the use of heavy cotton-

TABLE IX—*Cost of gains—low cottonseed-meal rations*

Lot No.	Year	No. of steers	Ration	Total gain	Total silage or hulls fed	Total cottonseed meal fed	Total cost of feed	Cost per pound gain	Average total gain per steer
				Lbs.	Lbs.	Lbs.		Cents	Lbs.
5	1909	21	Silage, 3, 4, 5 lbs. cottonseed meal	4527	113400	7560	$264.60	5.8	216.6
8	1910	8	Silage, 3, 4, 5 lbs. cottonseed meal	1158	43200	2880	100.80	8.7	144.7
3	1911	8	Silage, 3, 4, 5 lbs. cottonseed meal	823	43200	2880	100.80	12.3	102.9
11	1911	8	Silage, 3, 4, 5 lbs. cottonseed meal	1221	28800	2880	79.20	6.5	152.6
12	1911	13	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal	1527	29250	4680	175.50	11.5	117.5
5	1911	8	Silage, no meal 45 da., silage 7, 8, 9 lbs. meal 45 da.	817	43200	2880	100.80	12.3	102.1
1	1912	8	Silage, 3, 4, 5 lbs. cottonseed meal	1325	40960	2880	97.44	7.4	165.6
4	1912	8	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal	775	20920	2880	119.68	15.4	96.9
Total		82	Average					8.53	148.5

TABLE X—*Cost of gains—medium cottonseed-meal rations*

Lot No.	Year	No. of steers	Ration	Total gain	Total silage or hulls fed	Total cotton-seed meal fed	Total cost of feed	Cost per pound gain	Average total gain per steer
				Lbs.	Lbs.	Lbs.		Cents	Lbs.
1	1909	16	Silage, 5, 6, 7 lbs. cottonseed meal	2812	57600	8640	$194.40	6.9	171.1
3, 4	1910	8	Silage, 5, 6, 7 lbs. cottonseed meal	1382	36000	4320	108.00	7.8	172.7
2	1911	8	Silage, 4, 5, 6 lbs. cottonseed meal	1032	36000	3600	99.00	9.5	129.0
2	1912	8	Silage, 5, 6, 7 lbs. cottonseed meal	1255	40960	4320	115.44	9.2	156.9
5	1912	8	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	1331	20920	4320	137.68	10.3	166.4
7	1912	8	Silage, 6 lbs cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	1202	28881	4320	113.94	9.5	150.3
Total		56	Average					8.52	160.9

TABLE XI—*Cost of gains—high cottonseed-meal rations*

Lot No.	Year	No. of steers	Ration	Total gain	Total silage or hulls fed	Total cotton-seed meal fed	Total cost of feed	Cost per pound gain	Average total gain per steer
				Lbs.	Lbs.	Lbs.		Cents	Lbs.
7	1910	8	Silage, 7, 8, 9 lbs. cottonseed meal	1310	43200	5760	$136.80	10.5	163.7
4	1911	8	Silage, 7, 8, 9 lbs. cottonseed meal	992	43200	5760	136.80	13.8	124.0
13	1911	13	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal	1690	29250	9360	234.00	13.9	130.0
3	1912	9	Silage, 7, 8, 9 lbs. cottonseed meal	1275	40960	5760	133.44	10.5	159.4
6	1912	8	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal	1583	28881	5760	187.52	11.8	197.9
Total		45	Average					12.1	152.2

seed-meal feeding. None of the steers were troubled with blindness or serious digestive disorders. The amounts of feed consumed and the cost of gains are shown in Tables IX, X, and XI.

Cost of gain—varying amounts of cottonseed meal

The average cost of a pound gain with the lots receiving a low cottonseed-meal ration, of 3 to 5 pounds, was 8.53 cents; with lots receiving a medium cottonseed-meal ration, of 5 to 7 pounds, 8.52 cents; and with lots receiving a high cottonseed-meal ration, of 7 to 9 pounds, 12.09 cents.

General results on cottonseed-meal feeding

The general results from the work on cottonseed meal for steer feeding indicate, first, that the best and cheapest gains can be made when the amount of cottonseed meal fed increases from 5 to 7 pounds per head throughout the feeding period; second that the feeder is not warranted in the use of cottonseed meal to the extent of from 7 to 9 pounds per head per day, except in very short feeding periods, of from 30 to 50 days; and third, that medium meal rations are as efficient from the standpoint of gains as high meal rations, increasing from 7 to 9 pounds, and are much more efficient from the standpoint of economy.

TABLE XII—*Summary—silage vs. hulls, with varying amounts of cottonseed meal*

No. of experiments	No. of steers on experiment	Ration	Average total gain per steer	Average daily gain
			Lbs.	Lbs.
6	61	Silage and low meal	151.7	1.69
3	29	Hulls and low meal	111.2	1.24
3	32	Silage and medium meal	166.9	1.85
3	32	Hulls and medium meal	164.5	1.83
3	24	Silage and high meal	149.0	1.66
2	21	Hulls and high meal	163.9	1.82

Effect of varying amounts of cottonseed meal with silage vs. with cottonseed hulls

In these experiments an effort was made to find out the minimum amount of cottonseed meal with silage or hulls at which fattening steers would make the most profitable gains. In Table XII the data presented in the preceding tables have been compiled so that the silage and cottonseed-hull groups with the low, medium, and high cottonseed-meal rations are separated.

From Table XII we learn that when small amounts of cottonseed meal are fed, such as 3, 4, and 5 pounds, silage gives better results than cottonseed hulls, and that when large amounts are fed the cottonseed hulls give the better returns. The chief lesson to be learned is that medium amounts of cottonseed meal, such as 5, 6, and 7 pounds, give better returns than either low amounts or high amounts of cottonseed meal. When medium amounts of cottonseed meal are used there is not much difference in the gains when silage is fed and when hulls are fed. Which feed shall be used depends largely upon which is the cheaper. As large gains are made with a medium ration of cottonseed meal as with the high amounts of meal and at a much less cost, and when silage is used larger gains are made. The differences with high meal and silage, and high meal and hulls, are most likely due to the fact that the steers on silage and high meal scour more than steers on hulls and high meal.

SILAGE, COTTONSEED HULLS

When cottonseed meal was first used as a cattle feed in the South it was, of course, generally fed by farmers located near the oil mills, and naturally the most available roughage, cottonseed hulls, was used. Cottonseed hulls have thus come to have a commercial value. They have been so successfully fed that there has been a tendency to purchase and feed hulls on the part of some men on whose farms more valuable roughage in the form of corn stalks and straw was allowed to go to waste. Cottonseed hulls have a value of only $4.15 per ton as a fertilizer. There is not, therefore, the same incentive for their purchase for feeding purposes as for the purchase of meal.

When to feed hulls

It is not uncommon to see hulls fed to cattle on the farm when the cheap roughage feeds of the farm are being wasted in the fields. Instead of allowing the corn stover to waste in the fields it would be better to put it into the silo and feed it with cottonseed meal rather than purchase hulls to make up the roughage portion of the ration. Silage may be produced on the farm at a very much less cost than the purchasing price of cottonseed hulls. Tables XIII, XIV, and XV give the results of the feeding of cottonseed hulls in comparison with silage, with 231 steers in 23 experiments.

TABLE XIII—*Gains of steers fed silage*

Lot No.	Year	No. of steers	Ration	Average initial weight	Average final weight	Average gain per steer: 1st 30 days	Average gain per steer: 2nd 30 days	Average gain per steer: 3rd 30 days	Average total gain per steer	Average daily gain per steer
				Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
5	1909	21	Silage, 3, 4, 5 lbs. cottonseed meal	746.2	962.1	106.1	39.8	69.7	215.6	2.40
8	1910	8	Silage, 3, 4, 5 lbs. cottonseed meal	926.1	1070.9	61.6	49.0	34.1	144.7	1.61
3	1911	8	Silage, 3, 4, 5 lbs. cottonseed meal	831.5	934.4	50.6	33.1	19.6	102.9	1.14
11	1911	8	Silage, 3, 4, 5 lbs. cottonseed meal	733.1	885.7	38.4	46.4	67.9	152.6	1.70
1	1912	8	Silage, 3, 4, 5 lbs. cottonseed meal	1088.5	1254.1	55.9	48.5	61.2	165.6	1.84
1	1909	16	Silage, 5, 6, 7 lbs. cottonseed meal	841.9	1013.0	75.6	58.0	37.5	171.1	1.90
3, 4	1910	8	Silage, 5, 6, 7 lbs. cottonseed meal	957.0	1129.7	66.0	47.6	59.1	172.7	1.92
2	1911	8	Silage, 4, 5, 6 lbs. cottonseed meal	799.8	928.8	59.8	37.5	31.7	129.0	1.43
2	1912	8	Silage, 5, 6, 7 lbs. cottonseed meal	1115.2	1272.1	59.8	40.1	57.0	156.9	1.74
7	1910	8	Silage, 7, 8, 9 lbs. cottonseed meal	924.4	1088.1	50.1	52.0	61.6	163.7	1.82
4	1911	8	Silage, 7, 8, 9 lbs. cottonseed meal	812.0	936.0	53.0	21.4	49.6	124.0	1.38
3	1912	8	Silage, 7, 8, 9 lbs. cottonseed meal	1102.0	1261.4	62.4	35.5	61.5	159.4	1.77
Total		117	Average	822.9	1061.4	61.6	42.4	51.9	154.9	1.72

TABLE XIV—*Gains of steers fed cottonseed hulls*

Lot No.	Year	No. of steers	Ration	Average initial weight	Average final weight	Average gain per steer: 1st 30 days	2nd 30 days	3rd 30 days	Average total gain per steer	Average daily gain per steer
				Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
12	1911	13	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal	769.2	886.7	48.4	22.4	46.7	117.5	1.31
4	1912	8	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal	1107.4	1204.2	46.0	29.9	21.0	96.9	1.07
3	1909	16	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	850.4	1028.9	70.8	75.6	32.1	178.5	1.98
5, 6	1910	8	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	980.5	1129.1	62.7	69.0	16.9	148.6	1.65
1	1911	8	Cottonseed hulls, 4, 5, 6 lbs. cottonseed meal	821.5	940.9	26.1	53.3	40.0	119.4	1.33
5	1912	8	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	1091.1	1257.5	74.2	55.4	36.8	166.4	1.85
13	1911	13	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal	776.0	906.0	63.2	16.2	50.6	130.0	1.44
6	1912	8	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal	1094.6	1292.5	83.9	56.2	57.8	197.9	2.19
Total		82	Average	849.0	1080.7	59.4	47.3	37.7	144.4	1.60

TABLE XV—*Gains of steers fed a combination of silage and hulls*

Lot No.	Year	No. of steers	Rations	Average initial weight	Average final weight	Average gain per steer: 1st 30 days	Average gain per steer: 2nd 30 days	Average gain per steer: 3rd 30 days	Average total gain per steer	Average daily gain per steer
				Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
2	1909	16	Silage, 6 lbs. cottonseed hulls, 5, 6, 7 lbs. meal	829.0	1016.9	90.4	58.7	38.8	187.9	2.08
15	1910	8	Silage, 10 lbs. cottonseed hulls, 4, 5, 6 lbs. meal	781.3	958.3	59.1	59.5	58.4	177.0	1.97
2	1912	8	Silage, 6 lbs. cottonseed hulls, 5, 6, 7 lbs. meal	1116.4	1266.6	52.5	46.5	51.3	150.3	1.67
Total		32	Average	908.9	1080.6	67.3	54.9	49.5	171.7	1.91

Results from feeding hulls vs. silage

These results show that much better gains may be made through the use of silage with cottonseed meal than through the exclusive use of cottonseed hulls for the roughage portion of the ration. When silage is fed, however, greater gains may be made by the addition of a small amount of some dry feed, such as hulls. The total average gain per head for steers fed silage and cottonseed meal was 154.9 pounds; for steers fed cottonseed hulls and meal, 144.4 pounds; and for steers fed a combination of silage, hulls and meal, 171.7 pounds. If one consider only the medium meal rations, which were the most successful, the average gain per head for steers fed silage and cottonseed meal was 166.9 pounds; for steers fed cottonseed hulls and meal, 164.5 pounds; and for steers fed a combination of silage, hulls and meal, 171.7 pounds. Steers fed silage and cottonseed meal made 7.3 per cent better gains than steers fed cottonseed hulls and meal. Steers fed a combination of the three feeds made 18.9 per cent better gains than steers fed the cottonseed hulls and meal.

If we allow the value of the feeds used at $3.00 per ton for corn silage, $8.00 per ton for cottonseed hulls, and $25.00 per ton for cottonseed meal, then the cost of gains will be as shown in Tables XVI, XVII, and XVIII.

TABLE XVI—*Cost of gains—silage-fed steers*

Lot No.	Year	No. of steers	Ration	Total gain	Total silage fed	Total cotton-seed meal fed	Total cost of feed	Cost per pound gain	Average total gain per steer
				Lbs.	Lbs.	Lbs.		Cents	Lbs.
5	1909	21	Silage, 3, 4, 5 lbs. cotton-seed meal	4527	113400	7560	$264.60	5.8	216.6
8	1910	8	Silage, 3, 4, 5 lbs. cotton-seed meal	1158	43200	2880	100.80	8.7	144.7
3	1911	8	Silage 3, 4, 5 lbs. cotton-seed meal	823	43200	2880	100.80	12.3	102.9
11	1911	8	Silage 3, 4, 5 lbs. cotton-seed meal	1221	28800	2880	79.20	6.5	152.6
1	1912	8	Silage, 3, 4, 5 lbs. cotton-seed meal	1325	40960	2880	97.44	7.4	165.6
1	1909	16	Silage, 5, 6, 7 lbs. cotton-seed meal	2812	57600	8640	194.40	6.9	171.1
3, 4	1910	8	Silage, 5, 6, 7 lbs. cotton-seed meal	1382	36000	4320	108.00	7.8	172.7
2	1911	8	Silage, 4, 5, 6 lbs. cotton-seed meal	1032	36000	3600	99.00	9.6	129.0
2	1912	8	Silage, 5, 6, 7 lbs. cotton-seed meal	1255	40960	4320	115.44	9.2	156.9
7	1910	8	Silage, 7, 8, 9 lbs. cotton-seed meal	1310	43200	5760	136.80	10.5	163.7
4	1911	8	Silage, 7, 8, 9 lbs. cotton-seed meal	992	43200	5760	136.80	13.8	124.0
3	1912	8	Silage, 7, 8, 9 lbs. cotton-seed meal	1275	40960	5760	133.44	10.5	159.4
Total		117	Average					8.2	163.3

TABLE XVII—*Cost of gains—cottonseed-hull rations*

Lot No.	Year	No. of steers	Ration	Total gain	Total cottonseed hulls fed	Total cottonseed meal fed	Total cost of feed	Cost per pound gain	Average total gain per steer
				Lbs.	Lbs.	Lbs.		Cents	Lbs.
12	1911	13	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal	1527	29250	4680	$175.50	11.5	117.5
4	1912	8	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal	775	20920	2880	119.68	15.4	96.9
3	1909	16	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	2856	36000	8640	252.00	8.8	178.5
5, 6	1910	8	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	1189	18000	4320	126.00	10.6	148.6
1	1911	8	Cottonseed hulls, 4, 5, 6 lbs. cottonseed meal	955	18000	3600	117.00	12.3	119.4
5	1912	8	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	1331	20920	4320	137.68	10.3	166.4
13	1911	13	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal	1690	29250	9360	234.00	13.9	130.0
6	1912	8	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal	1583	28881	5760	187.52	11.8	197.9
Total		82	Average					11.3	145.2

TABLE XVIII—*Cost of gains—combination of silage and cottonseed hulls*

Lot No.	Year	No. of steers	Ration	Total gain	Total silage fed	Total cottonseed hulls fed	Total cottonseed meal fed	Total cost of feed	Cost per pound gain	Average total gain per steer
				Lbs.	Lbs.	Lbs.	Lbs.		Cents	Lbs.
2	1909	16	Silage, 6 lbs. cottonseed hulls, 5, 6, 7 lbs. c.-s. meal	3006	43200	8640	8640	$207.36	6.9	187.9
15	1910	8	Silage, 10 lbs. cottonseed hulls, 4, 5, 6 lbs. c.-s. meal	1416	21600	7200	3600	106.20	7.5	177.0
7	1912	8	Silage, 6 lbs. cottonseed hulls, 5, 6, 7 lbs. c.-s. meal	1202	28881	4320	4320	113.94	9.5	150.3
Total		32	Average						7.6	175.7

Comparison of cost of gains, hulls vs. silage

Eight experiments with 82 steers showed that the average per lot with cottonseed hulls was smaller than where the steers were fed silage. The average cost of a pound gain with cottonseed hulls was 11.3 cents, while for silage-fed lots the cost was 8.2 cents. The largest and most economical gain was made where a small amount of hulls was fed in conjunction with the silage, at a cost of 7.6 cents per pound. If one consider again only the medium meal rations the cost of a pound gain with the cottonseed-hull ration was 8.2 cents; with the silage-fed lots, 10.4 cents; and with the lots fed a combination of silage, hulls and meal, 7.6 cents.

These experiments seem to indicate that cottonseed hulls or their roughage equal should make up but a very small portion of the ration in steer feeding where silage is produced on the farm. From 8 to 16 tons of silage can be produced on each acre of Tennessee land, and this silage is worth more for cattle feeding purposes at $3.00 per ton than cottonseed hulls are worth at $8.00 per ton. It is also true that during the course of these experiments cottonseed hulls reached on the market a selling price per ton of $13.00. In these experiments silage-fed steers made 7.27 per cent greater gains at 27.7 per cent less cost than steers fed cottonseed hulls.

Farm values of silage and cottonseed hulls

The usual method of figuring profits in fattening steers is to charge market prices of feeds on board cars at the nearest shipping station to where the steers are fed, and what is left above cost of feed and labor is declared as profit. Some feeders maintain that cattle feeding is highly profitable if but market prices for feeds can be obtained because of the increased fertility and organic matter that is retained on the farm. Indeed, the maintenance of fertility has become a serious problem with many farmers. Steer feeding will pay if but market prices can be obtained for farm products; and, indeed, much produce like rough hays and corn stover and the straws can be marketed through beef cattle that would otherwise return to the land without a market value. If this point of view of cattle raising were considered a great many more farmers would feed beef cattle. An attempt is made in this part of the bulletin to determine a farm value for silage, also for cottonseed hulls, when fed to steers that sell for 7 cents per pound and that are fed on a $1.50 margin. In Table XIX the market price paid for cottonseed meal was charged against it and the farm value of silage was determined.

TABLE XIX—*Farm value of silage*

Lot No.	Year	No. of steers	Ration	Total gain	Total silage fed	Total cottonseed meal fed	Total cost cottonseed meal fed	Total difference between cost and selling price*	Returns per ton silage fed
				Lbs.	Lbs.	Lbs.			
5	1909	21	Silage, 3, 4, 5, lbs. cottonseed meal	4527	113400	7560	$ 94.48	$552.07	$8.07
8	1910	8	Silage, 3, 4, 5 lbs. cottonseed meal	1158	43200	2880	36.00	192.22	7.23
3	1911	8	Silage, 3, 4, 5 lbs. cottonseed meal	823	43200	2880	36.00	157.64	5.63
11	1911	8	Silage, 3, 4, 5 lbs. cottonseed meal	1221	28800	2880	36.00	173.44	9.54
1	1912	8	Silage, 3, 4, 5 lbs. cottonseed meal	1325	40960	2880	36.00	223.32	8.93
1	1909	16	Silage, 5, 6, 7 lbs. cottonseed meal	2812	57600	8640	108.00	393.69	9.91
3, 4	1910	8	Silage, 5, 6, 7 lbs. cottonseed meal	1382	36000	4320	54.00	211.52	8.73
2	1911	8	Silage, 4, 5, 6 lbs. cottonseed meal	1032	36000	3600	45.00	168.84	6.86
2	1912	8	Silage, 5, 6, 7 lbs. cottonseed meal	1255	40960	4320	54.00	221.71	8.16
7	1910	8	Silage, 7, 8, 9 lbs. cottonseed meal	1310	43200	5760	72.00	242.65	7.89
4	1911	8	Silage, 7, 8, 9 lbs. cottonseed meal	992	43200	5760	72.00	166.90	4.39
3	1912	8	Silage, 7, 8, 9 lbs. cottonseed meal	1275	40960	5760	72.00	221.36	6.88
Total		117	Average returns per ton silage fed						$7.65

* The cost price for each group of steers is placed at 5.5 cents per pound; the selling price at $1.50 margin from cost price per hundred pounds.

Farm value of silage This table gives the results of the feeding of 117 steers in 12 experiments on cottonseed meal and silage. In these experiments the average price obtained for the silage fed was $7.65 per ton. There were fed 28.6 tons of cottonseed meal, which returned to the soil after passing through the steers, not less than $629.20 worth of fertilizer constituents. The manure from the silage portion of the ration fed must have been worth not less than $354.00. The total value of the manure returned to the soil was, then, not less than $983.20, and $7.65 was obtained for every ton of silage fed.

In Table XX the same calculations were made where cottonseed hulls instead of silage were fed with cottonseed meal in the ration. Eighty-two steers were fed in eight experiments.

TABLE XX—*Farm value of cottonseed hulls*

Lot No.	Year	No. of steers	Ration	Total gain	Total cottonseed hulls fed	Total cottonseed meal fed	Total cost cottonseed meal fed	Total difference between cost and selling price	Returns per ton hulls fed
				Lbs.	Lbs.	Lbs.			
12	1911	13	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal	1527	29250	4680	$ 58.50	$256.92	$13.56
4	1912	8	Cottonseed hulls, 3, 4, 5 lbs. cottonseed meal	775	20920	2880	36.00	185.69	14.31
3	1909	16	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	2856	36000	8640	108.00	404.02	16.41
5, 6	1910	8	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	1189	18000	4320	54.00	200.99	27.26
1	1911	8	Cottonseed hulls, 4, 5, 6 lbs. cottonseed meal	955	18000	3600	45.00	165.50	13.39
5	1912	8	Cottonseed hulls, 5, 6, 7 lbs. cottonseed meal	1331	20920	4320	54.00	223.12	16.20
13	1911	13	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal	1690	29250	9360	117.00	269.62	10.43
6	1912	8	Cottonseed hulls, 7, 8, 9 lbs. cottonseed meal	1583	28881	5760	72.00	240.09	11.64
Total		82	Average returns per ton cottonseed hulls fed						$13.78

Farm value of hulls

In the foregoing experiment $13.78 was obtained for cottonseed hulls fed to steers when the margin was $1.50 and the steers sold at 7 cents per pound.

Comparison of farm value of silage vs. hulls

It requires a much wider margin to feed steers with hulls than with silage. The average profit per steer fed hulls was $7.28 when hulls cost $8.00 per ton, while the average profit per steer fed silage, when the purchase price of silage is $3.00 per ton, was $11.28.

The feeder should bear in mind the fact that silage may be produced on the farm at a cost not to exceed $2.00 per ton while hulls often sell at a price nearly equal to that obtained for them in these experiments. Once during the progress of these experiments they reached the selling price of $13.00 per ton. It should also be borne in mind that these values have been established on a definite margin of $1.50. Had a margin of only $1.00 been allowed in the calculation of the above data, then but $9.57 per ton would have been obtained for each ton of hulls fed.

INFLUENCE OF TYPE AND BREEDING UPON THE RATE OF GAIN

In the beginning of each experiment the steers were divided into groups as nearly equal in type and quality as possible. During the autumns of 1910 and 1911, after division into groups, each steer was described in the experimental notes according to color, breed characteristics, and feeder type. If a steer appeared to have one or more crosses of some pure breed, it was described as belonging to that breed. At the close of the experiment gains of breeds belonging to the beef type were totalled, as were also the gains of the steers belonging to dairy breeds and scrubs. The following gains were noted for the years 1910 and 1911:

TABLE XXI—*Influence of breed on gains*

Breed	Year	No. of steers	Total gain 90 days	Average gain 90 days per steer	Average gain for the two years
			Lbs.	Lbs.	Lbs.
Beef	1910	36	6341	176.1	146.7
	1911	95	11131	117.3	
Dairy	1910	11	1504	136.9	--------
	1911	----------	------------	------------	
Scrub	1910	33	4462	135.1	121.1
	1911	21	2250	107.1	

Influence of breeding on gains

Data were obtained on 196 head of steers. In 1910 steers that were the result of one or more crosses of a beef breed made 39.2 pounds more gain than steers in which dairy blood predominated; beef-bred steers made 41.0 pounds more gain than scrub steers. Dairy-bred steers and scrub steers made practically the same gains. There were no steers in 1911 that showed dairy breeding. Beef-bred steers in 1911 made, under the same conditions, 10.2 pounds more gain than scrub steers. The average for the two years showed a gain of 25.6 pounds in favor of the steers with one or more beef-bred crosses. Not only did the better-bred steers make more gains, but the gains were put on in the more valuable beef cuts, and thus made the beef-bred steers sell at a wider margin and greater profits.

Influence of type on gains

Each steer was also described according to the feeder type, regardless of breed characteristics. The following classification of feeder types was made, viz., poor, medium, good, and very good. According as a steer possessed heavy quarters, a broad back, depth in the heart girth and digestive capacity, and had good quality as indicated by a pliable skin and soft coat of hair, it was described as very good, good, medium, or poor, as in the estimation of the judges it would grade. In this classification breed characteristics were ignored as far as possible. That this was done may be shown by the fact that four scrubs in 1910 were classified as "very good." Scrubs so classified, however, made lower gains than beef breeds of the same classification. Table XXII shows the gains according to type for both years.

TABLE XXII—*Influence of type on gains*

Type	Year	No. of steers	Total gain 90 days	Average gain 90 days per steer	Average gain for the two years
			Lbs.	Lbs.	Lbs.
Very good	1910	17	2948	173.8	158.8
	1911	7	1006	143.7	
Good	1910	37	5751	155.4	143.6
	1911	28	3686	131.6	
Medium	1910	17	2263	133.4	122.0
	1911	53	5868	110.6	
Poor	1910	9	1340	148.8	124.9
	1911	28	2826	100.9	

In 1910 steers that were of very good beef type made 25.0 pounds more gain than steers of poor type and 40.7 pounds more gains than steers of medium type. In 1911 steers of the best beef type gained 43.7 pounds more than steers of the poorest type. The average gain of 24 steers of the best type for the two years was 33.9 pounds higher than the average gain of 37 steers of the poorest type. Twenty-four steers of the best type made as much gain as 32 steers of the poorest type. In other words, it took 8 more steers of the poorest type, and the feed that was given them, to make the gain that was made by the best type.

During the first year's work of these experiments (the winter of 1909-1910) each lot was divided into "good" and "poor" groups and fed separately. There were 24 steers classified as "good" and 24 steers classified as "poor." The two groups were fed as nearly as possible under the same conditions. The steers classified as "good" made 4.15 per cent better gains than the steers classified as "poor."

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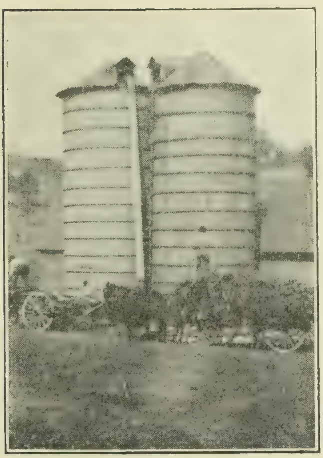
THE TENNESSEE WOODEN-HOOP SILO

BY

C. A. WILLSON



KNOXVILLE, TENNESSEE

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The Experiment Station building, containing the offices and laboratories, and the plant house and part of the Horticultural Department, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy building, etc., are located one mile west of the University on the Kingston Pike. The fruit farm is adjacent to the Industrial School and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

THE TENNESSEE WOODEN-HOOP SILO

For a number of years there has existed in the Sweetwater Valley of East Tennessee a type of silo known as the Tennessee Wooden-hoop Silo, and from there it has spread to various areas throughout East Tennessee. This type of silo is homemade and can be constructed more cheaply than any other silo now on the market, thus making it possible for every farmer to have a silo. It may be constructed at a cost of from $60 to $100, and will last from eight to twelve years when well constructed, of good material. Mr. J. W. McGhee, owner of the Stony Point Dairy, Cleveland, Tennessee, writes, "My older silo has been filled nine times, is now in good condition, and is, I think, good for nine more years. It is 14 ft. 8 in. in diameter by 26 ft. high, and cost me $65 besides the hoops and about four days' labor by myself. I am sure that the wooden-hoop silo is the silo for the majority of the farmers to build on account of the ease of construction and the cheapness with which it can be built."

Size of silo

The first thing to consider in building a silo is the diameter, for if the diameter is too large the silage cannot be fed out rapidly enough to prevent spoiling, especially if the weather happens to be warm. The table given below shows the smallest number of cows that should be fed from silos of given diameters.

Diameter of silo in feet	Number of cows to be fed
10	12
12	17
14	23
16	30

The table is based upon the feeding of from 30 to 40 pounds of silage to each cow during the feeding period. One of the commonest mistakes is to make the silo too great in diameter. It must not be so large that the silage cannot be fed off at the rate of at least an inch per day in order to prevent the silage from spoiling. It is better to have the silo a little too small than to have it too large. An excellent plan is to have a fair-sized silo for the winter feeding and a smaller silo to use for summer feeding in case the pasturage should become short. In height the silo should be at least two times the diameter, and best results are secured if it is not under 30 to 32 feet high, inside measurement.

Foundation

Some of the capacity of the silo may be secured by means of a pit. It would not seem advisable, however, to make the pit more than 5 feet below the surface of the ground, owing to the fact that the expense of getting the silage out of the pit would be greater than would be the expense of putting it into the silo above ground by means of machinery. Then, too, not much is gained with this kind

of silo from making the pit deeper than 5 feet because the expense of digging the pit is as great as the expense of building the superstructure. The foundation must be made deep enough to be upon solid ground. If good, hard dirt is struct, from 1 to 2 feet is sufficiently deep to put the foundation wall. It should extend from 1 to 2 feet above ground on the higest side if the ground is sloping, to prevent rotting of the staves. To lay out the foundation, drive a stake in the ground at the center of the proposed site. Saw off this stake at the height desired for the foundation wall. One end of a straight 2x4 scantling, a little longer than is necessary to reach from the center of the silo to the outside wall of the foundation, should be nailed on top of the stake with a 40-penny spike. This spike then makes the exact center of the silo. From the spike, measure off on the scantling the distance to the outside and to the inside of the proposed foundation wall. If the ground is not level the marker may be made as shown in Fig. 2.

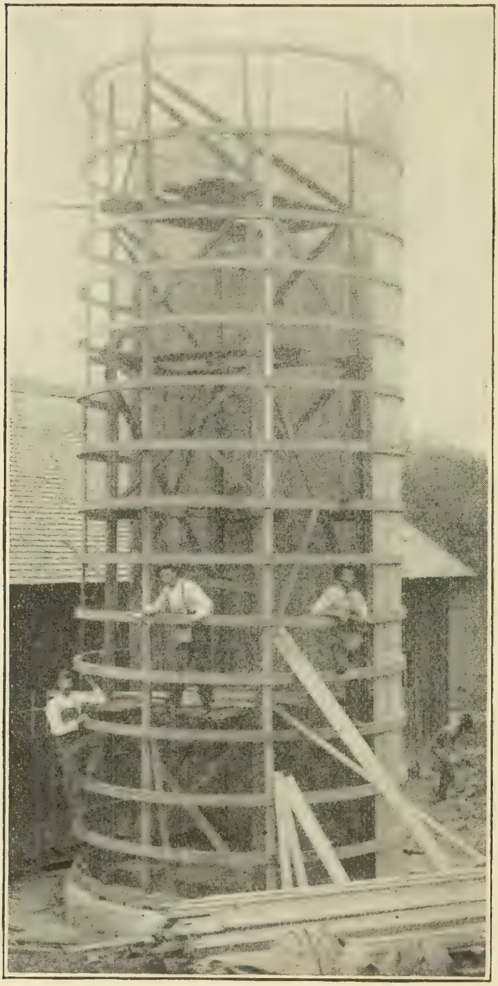

FIG. 1, SILO IN COURSE OF CONSTRUCTION

The pieces **a** and **b** are nailed to the 2x4, while **c** and **d** are held so that they can be moved as the ground becomes lower or higher. The marks thus made will be equidistant at all points from the center of the proposed silo. The foundation wall should be 6 to 7 inches thick, and the inside of the wall should be an inch or so nearer the center of the silo than will be the inside of the staves when the

silo is complete. This will allow for slight errors that may occur in the construction of the silo. The foundation should be made of concrete, and the dirt in the center of the silo may be left to make the form for the concrete work below ground. The dirt between the two circles made should be removed to the depth of the desired pit, and the ditch filled with concrete to the level of the ground. The forms for the part of the foundation wall that is to be above ground may be made of cheap material that will bend to a circle. Enough of the material that is to be used for the hoops may be ordered so that extra pieces may be made into forms for the foundation wall. After filling the ditch to the surface with a concrete mixture of 1 part cement, 3 parts sand, and 5 parts broken stone, or river rock, drive stakes down

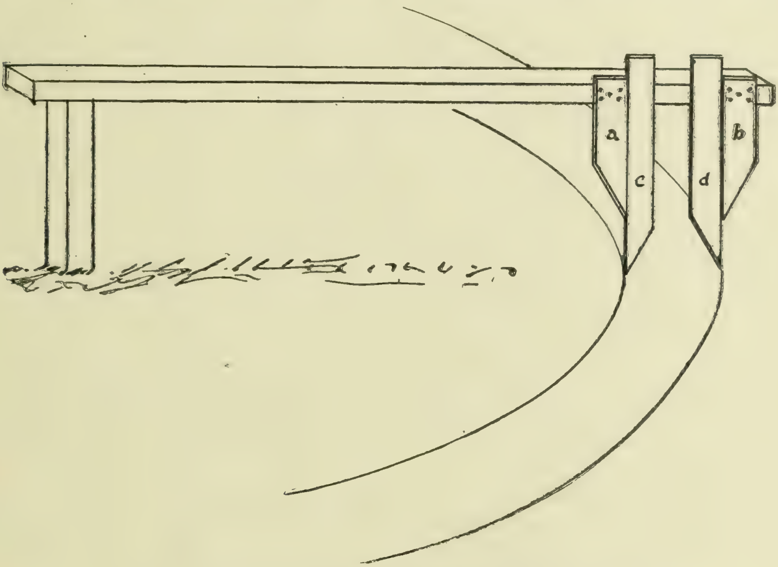

FIG. 2, METHOD OF LAYING OUT THE FOUNDATION

½ inch from the concrete and 2 feet apart all the way around on the inside and the outside of the wall. With the straight edge used before as a marker, or guide, the stakes can be driven down until they are on a level and at the height of the proposed wall. Take some of the poorer grades of the ½-inch hoop material and bend around the stakes, keeping the edge level with the top of the stakes. After the inside form is finished the outside form can be made in the same way, so that the level instrument will just miss the top of the inside form. At several places braces must be nailed across from one form to the other to prevent spreading as the form is filled in. If the wall extends more than a foot above the ground it should be reinforced with wire or iron rods put in the concrete near the top of the foundation wall. After each layer of concrete is packed, a spade, or, better still, a wide

goose-necked hoe which has been straightened out, should be run down between the concrete and the forms in order to force the stones away from the outside surface. This will leave the surface of the wall smooth when it is finished. Eye-bolts may be set in the foundation wall near the outside surface to be used for an anchor for the lower part of the silo. After the foundation wall has become hardened the dirt from the inside of the silo may be removed and the inside of the wall pointed and smoothed. If there is no danger of seepage water there is not so much need of a concrete floor to the silo, although it will give a much better finish, and the silage will be better at the bottom. It is advisable to have the bottom of the pit in the form of a kettle and to have a drain leading from it. The concrete at the bottom of the silo need not be more than 2 inches thick.

Materials for the silo The staves should be of the best grade heart-pine flooring, free from knot-holes, sapwood, and bad edges. It may be purchased in any length desired up to 20 feet. Odd lengths may be used, provided the pieces are long enough to reach from one hoop to the next, although the fewer short pieces there are the stronger will be the silo. The hoops should be of green white oak which has been sawed ½x4 inches, planed on all sides, and made into hoops while green. Seasoned material may be used if it has been tied in a creek for a week to ten days before it is wanted for the hoops.

Making the hoops The hoops may be made during the winter months or during the rainy days. The material for the hoops should be sized and planed. This is not necessary, but a much better job can be done and the hoops will last much longer. There are different methods of making the hoops. The most common method is to make all the hoops before beginning to set up the silo.

Another method is to make only about four of the hoops at first—one each for the bottom and the top of the silo and two to be placed where the joints will come; then after setting up the silo in this manner, make the remainder of the hoops on the silo by nailing them around the silo, each ply on the preceding one until the hoops are 4-ply thick. The latter method is recommended by some people who claim the advantage that less scaffolding is required. The former method has the advantage that all the hoops can be made at odd moments that could not otherwise be well utilized, and also that less time is required for the construction of the silo.

To make the hoops as above suggested there must be a solid platform as large across as the diameter of the silo. A barn floor is an excellent place on which to make them. If one has not a barn floor that is large enough, or that can be made large enough, then a platform of the right size must be made. After making the platform drive a nail in the center, and from this point describe a circle with a diameter 2 inches larger than the diameter of the proposed silo. Next nail 2x4 pieces, 10 inches long, just inside the circle with one

end flush with the circle described. These pieces should be nailed one every 2 feet on the circle. Next nail with one large spike on the outside of the circle, just opposite the first blocks nailed down, some 2x4 blocks, 8 inches long. The spike in these blocks should be driven half way the length of the block and into the platform 4½ inches from the end of the opposite inside block. These blocks should be sawed with a sloping cut at each end. After the blocks are in place the hoops may be made. Place the hoop material against the ends of the

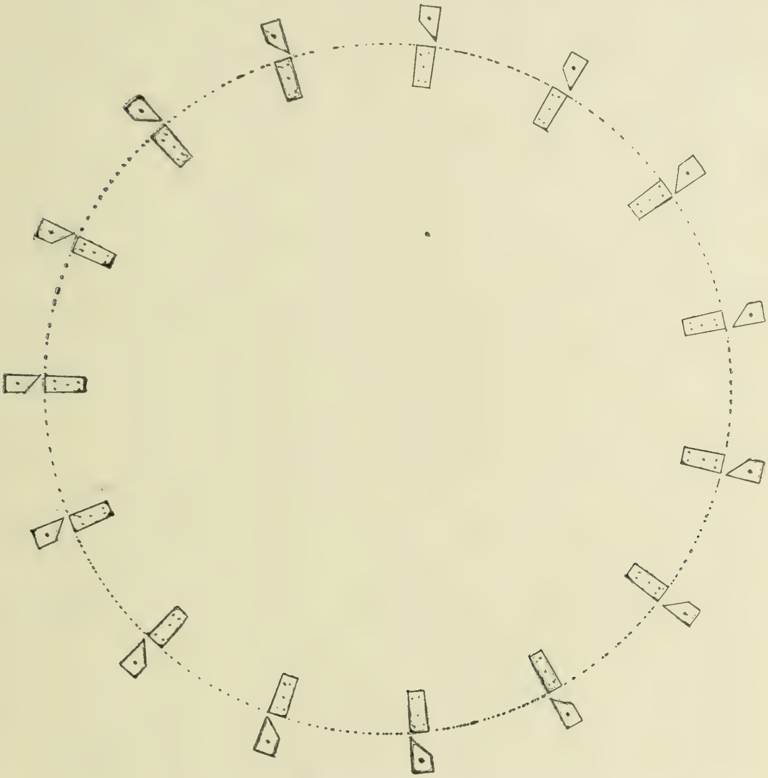

FIG. 3, METHOD OF LAYING OUT BLOCKS FOR MAKING HOOPS

inside blocks and hold in place by turning the blocks on the outside of the circle. After the first layer of the hoop material has been wrapped around the blocks put the second layer around, being careful to break joints by at least 5 feet distance, and when in place nail with nails nearly long enough to reach through the two layers. Continue by layers until the hoop is 4-ply thick. Use longer nails for each successive layer, for the strength of the hoops depends upon proper nailing. Be careful to have the inside layer of the hoop touching all the blocks before beginning to nail the second layer, for otherwise

all the hoops will not be of the same size, which is a very important point in the construction of the silo. There should be enough hoops so that the lower hoops will be 20 to 24 inches apart and the upper hoops 30 inches apart. After the hoops are made they can be thoroughly painted with creosote paint, which will make them last much longer. In fact, all the lumber of the silo should be painted with creosote paint. This can be done much more easily if the stave material is laid on sawhorses and painted before it is made into the silo.

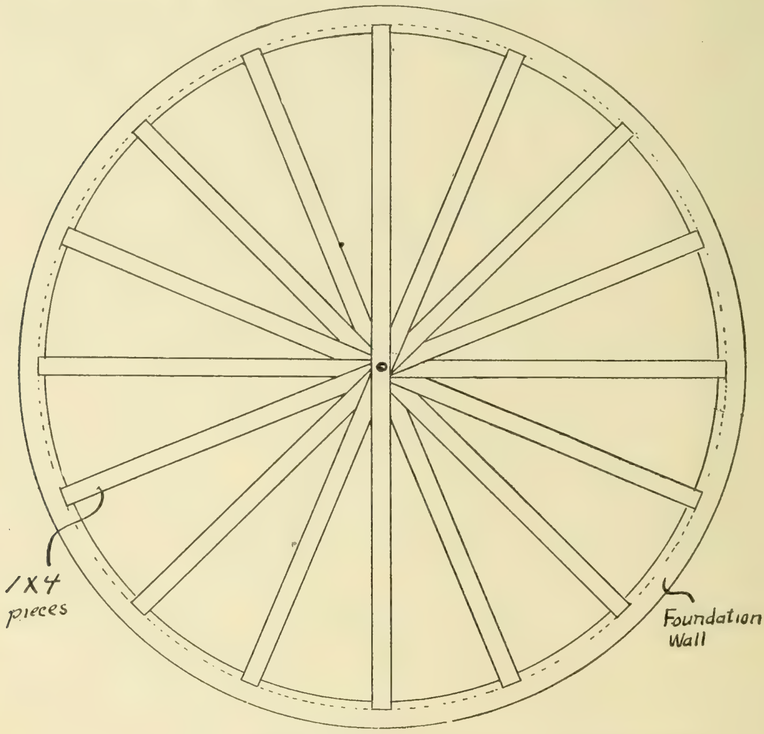

Fig. 4, Method of Making Hoop by Means of Crosspieces

There is still another way of making the hoops that is recommended by some people. After the foundation wall for the silo is built, 1x4-inch strips, 2 inches longer than the diameter of the silo, are laid across the foundation of the silo and are tacked at the center. In order that the ends may be on a true circle it is better that each of the pieces have a hole bored through it at a point exactly one-half the length of the piece. A bolt should then be put through the hole connecting all the pieces. Eight pieces should be used, which will make 16 points of contact for forming the hoops. Figure 4 shows the crosspieces laid on the foundation wall ready for the construction of the hoops. However, if they are measured correctly and the

bolt is put in the proper place, the hoops may be made anywhere else with this device. Tack the first layer lightly at the ends to the ends of the pieces and remove the nails as the second layer of hoops is being nailed to the first layer. The pieces that have been bolted together may be passed on to some neighbor to be used in the construction of another silo.

Setting up the silo

The first step in setting up the silo is to place all the hoops on the foundation. Build scaffolding on the inside of the silo by setting up five poles as close to the foundation wall as possible. Raise the top hoop from the foundation to the top of the silo and hold in place by means of crosspieces extending out from the scaffolding poles. At this point it is well to run guy wires from the tops of the scaffolding poles, in order to insure the safety of the scaffolding and to keep the silo in position until it is complete. Raise each hoop into place and hold in place by crosspieces from the scaffolding. Another method of holding the hoops in place is to put up five or six temporary staves and fasten the hoops to them. The staves may now be nailed on the hoops. Begin putting on the staves by putting the first stave at one side of the place where the door opening is to be and nailing well after it is plumbed. From this point begin nailing on the staves, being careful to draw up all the staves well with nails as they are being nailed on. Nail them on by the usual method of putting down flooring and put the side out that would be laid up in laying a floor; then the silo will be tight on both sides. This is a very important point. Put two nails in the stave at each hoop. If the staves are not of sufficient length for the silo use alternate lengths so as to prevent all the joints from coming on the same hoop. Make all joints meet half way on the hoop. Begin nailing alternately at the top and the bottom so that neither end will get ahead.

Making the doors and the door opening

After ceiling around to nearly where the first stave was put on, leave a 2-foot space for the door opening. Next nail a stave on top of the others 2 inches back from the opening in order to make a jamb for the continuous door opening. The doors may be made of the stave material put crosswise of the door opening. Set a stave on each side of the door opening and toenail lightly through the edge of the hoops. These staves are to serve as the cleats for the doors. Begin at the bottom and nail to the two staves just mentioned pieces of stave material, crosswise of the door opening, until the top of the silo is reached. Now begin at the bottom of this continuous door on the outside of the silo and number on the door each space between the hoops. Next loosen the continuous door at the top and saw the cleats at a point half way between the edges of each hoop. Continue loosening and sawing of the cleats at each hoop until the whole continuous door is sawed into as many doors as there are spaces between the hoops. When this is done each door will be numbered and may be put in the place that it was made to fit, when the silo is being filled.

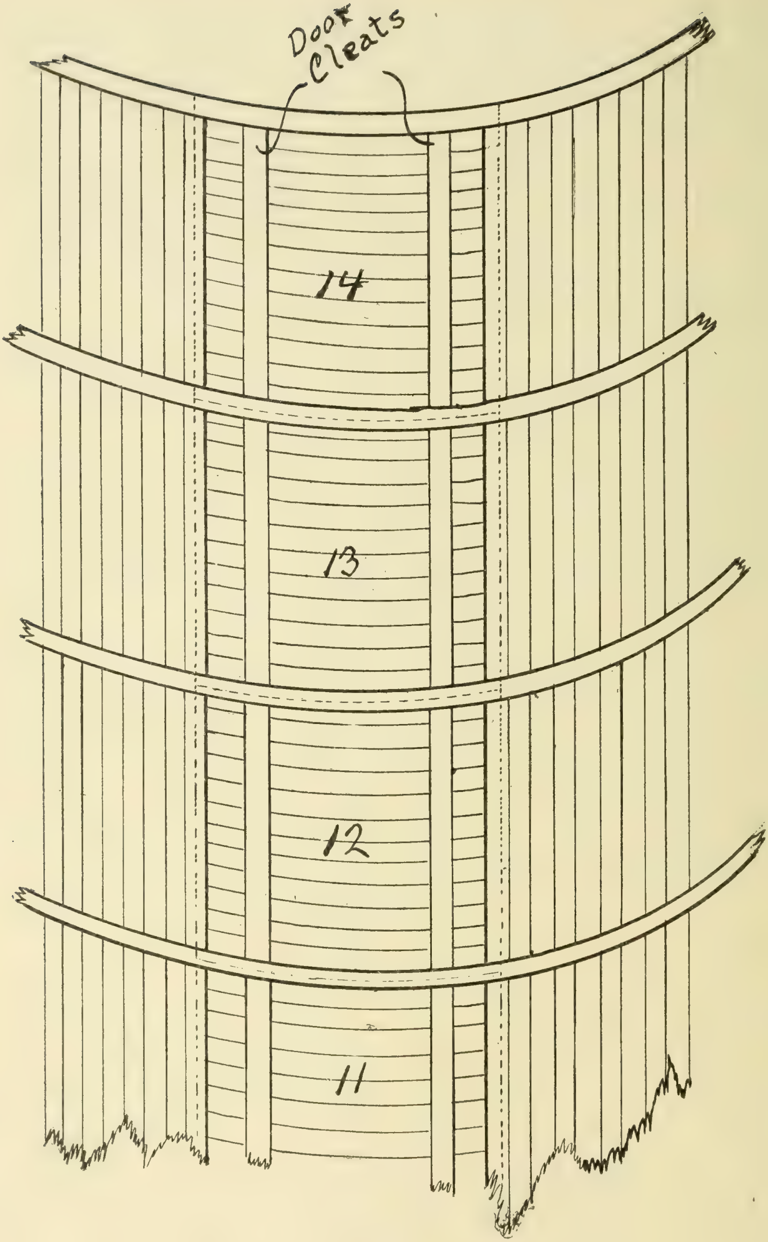

FIG. 5, METHOD OF MAKING DOORS

When the silo is being filled tighter joints may be made at the doors by the tacking of tar paper against the doors as they are put into place.

Ladder and chute

The hoops will serve as a ladder, for there is sufficient space between the hoops and the doors for finger and toe holds. The chute can be built next. Make the chute with about a 34-inch square opening.

Roof

Although not an absolute necessity in this climate, a roof will add much to the appearance and the life of the silo, as well as make it more agreeable for the feeder during stormy weather. The roof may be made of shingles or metal roofing as desired.

Variation of the wooden-hoop silo

Modifications of the above method of making the wooden-hoop silo are sometimes adopted in order to make the silo still cheaper. The hoop material is not always sized and planed, although it will make better hoops if so treated. Neither are the staves always made of dressed pine flooring. In some instances they are made of rough oak lumber, 1x4 inches by 12 or 16 feet, and nailed to the hoops, two thicknesses, with paper between. The paper in this case should be of the best grade ruberoid roofing. The boards should be so laid as to break joints.

Anchor for silo

All wooden silos of whatever description should be so anchored that there is no danger of their blowing over. Pass about three eye-bolts, equidistant, through the top hoop, and attach a double strand of No. 9 wire to each eye-bolt and to a long eye-rod that has been imbedded in concrete about 6 feet from the silo. Take up the slack of the wires by twisting them after they are fastened.

Cost of construction

The wooden-hoop silo can on the average be built for $1.00 per ton capacity. If the material for the hoops be furnished and the labor be done by the person who owns the silo, the actual cash outlay may not exceed 60 to 70 cents per ton capacity of the silo to be constructed. Below is given a representative bill of material and labor for building a silo 14 feet in diameter and 28 feet high, with a 4-foot pit, making the height of the inside measurement 32 feet and the capacity of the silo 100 tons.

BILL OF MATERIAL AND LABOR, SILO 14 x 32 FEET

Lumber	
1600 ft. matched flooring 1x4 at $25	$ 40.00
1000 ft. ½x4 hoop material at $20	20.00
Cement, sand and stone	
3 bbls. cement at $2.40	7.20
4 yds. sand at 50 cents	2.00
2 yds. stone at 40 cents	.80
Hardware	
75 lbs. cement-coated 8d. nails at 3 cents	2.25
Labor	
10 days carpenter labor at $2.00	20.00
10 days common labor at $1.00	10.00
Horse labor	6.00
Total cost	$108.25

The low cost of construction of the wooden-hoop silo makes it possible for every farm to have a silo. The durability of this silo, when well constructed, makes it compare favorably with any other type of wooden silo.

ACKNOWLEDGMENTS

The author wishes to express his obligations, for valuable suggestions and criticisms, to F. R. Hines, Knoxville, Tenn.; C. A. Hutton, Dairy Specialist of Southern Railway, Knoxville, Tenn.; H. N. Camp, Jr., Knoxville, Tenn.; and J. W. McGhee, Cleveland, Tenn.

Agricultural Experiment Station
OF THE
University of Tennessee

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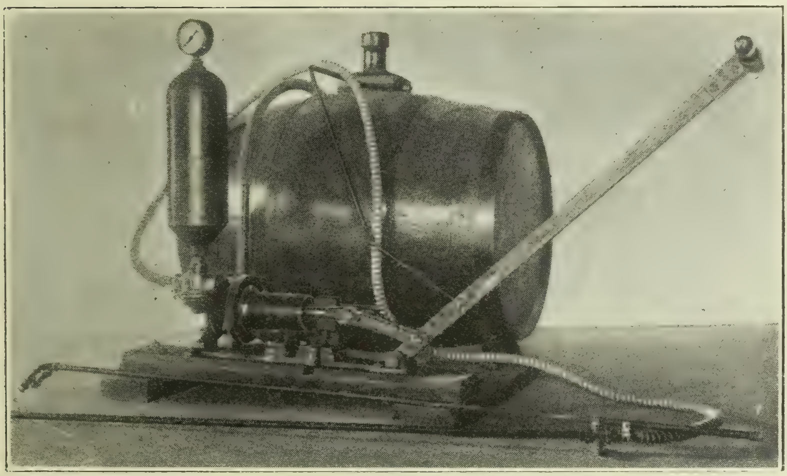
SUGGESTIONS FOR THE CONTROL OF INJURIOUS INSECTS AND PLANT DISEASES

BY
G. M. BENTLEY



A SIMPLE, DURABLE AND EFFICIENT BARREL SPRAYER

KNOXVILLE, TENNESSEE

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The Experiment Station building, containing the offices and laboratories, and the plant house and part of the Horticultural Department, are located on the University campus, 15 minutes walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy building, etc., are located one mile west of the University on the Kingston Pike. The fruit farm is adjacent to the Industrial School and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

SUGGESTIONS FOR THE CONTROL OF INJURIOUS INSECTS AND PLANT DISEASES

Many people believe that insects and fungi are controlled only by applications of chemical preparations, and give little attention to the prevention of attacks by cultivation, drainage, planting and rotation, based upon a knowledge of the habits and life histories of the pests. This impression has led us to give the suggestions below regarding preventive measures.

PREVENTIVES

In general

While much may be accomplished in the control of insects and fungous diseases by the use of insecticides and fungicides, more attention should be given to the prevention of the introduction of crop pests by judicious legislation, to the selection of resistant plants, to the elimination of weeds and worthless plants which harbor pests or act as intermediary hosts and are often of the same family as those under cultivation, to judicious rotation of crops, and to better drainage, cultivation and fertilization.

Cultural methods

Cultural methods of overcoming attack and injury by pests are based upon a knowledge of their habits and life histories. Simple rotations, season of planting, the use of trap plants, fall plowing, early planting, and many other average operations of the farm, if done with an intelligent knowledge of the habits and development of the pests to be controlled, will often of themselves prove decidedly efficient.

Rotation

The succession of the same or similar crops on the same land has proved disastrous in more ways than by the reduction of soil fertility. Its encouragement of the increase of insects and fungi has become notorious. The corn root-worm, boll worm (or corn ear worm), Hessian fly, and many other pests are more or less affected by crop rotation, and their control by this method should be carefully studied.

In sections affected with contagious diseases of live stock pasture rotation is essential. In the control of stomach and intestinal worms in sheep, hogs and cattle, intelligent rotation covering definite periods, based upon longevity and life history of the pests, is now recognized as the most available and economical plan.

The fever cattle tick may be permanently eradicated by positive rotation. It has been found that if cattle and horses are removed from a pasture during the summer months it becomes free from ticks. During the winter if infested cattle are run upon a cornfield or other cultivated field upon which no animals have been during the summer all the ticks will drop off, after which the animals may be placed upon the pasture that was freed of ticks during the previous summer. The Tennessee Experiment Station has prepared a bulletin upon the eradication of the tick by pasture rotation methods, which may be had on application.

Beneficial insects

While it may seem anomalous, probably the greatest factors in the control of insects, at least, are other insects and fungous diseases which are parasitic within or upon them. Such are truly friends of the producer, but they cannot be brought thoroughly under his control unitl insect life is better understood. Unable to identify these friends or to understand their operations, man too often treats them as enemies or minimizes their mission.

Birds

Birds as factors in insect control should be recognized. It is not uncommon to find large numbers of birds doing effective work in controlling insect outbreaks.

Insecticides and fungicides

Insecticides are substances which kill insects. Fungicides are substances which destroy fungous diseases. When insects and fungous diseases prevail upon the same plants insecticides and fungicides may be combined and the two results gained from one application. Variable results have been obtained from the use of insecticides and fungicides, due largely to climatic conditions and to the quality, age and preparation of the ingredients used and the combinations made. A knowledge of the pest being treated and the nature of the plant infested is an important consideration.

For remedial treatment, insects are divided, according to their manner of feeding, into biting and sucking groups. Hence, in the economic application of insecticides a knowledge of the mouth parts of insects is essential. To obtain this one has only to notice carefully the damage being done or study the insect and observe whether its mouth is provided with jaws for biting (chewing) or a beak for sucking. Until a distinct familiarity with insect anatomy and general classification is procured it may be better to send specimens to the Experiment Station for identification and remedial suggestion. Specimens should be accompanied by pieces of plants upon which they feed, and if possible some samples of the character of the damage done.

INSECTICIDES FOR BITING INSECTS

(Potato beetle, flea beetle, codling moth, currant worms, etc.)

1. PARIS GREEN (DRY).

Paris green .... 1 pound
Flour or
Land plaster or
Slaked lime ....20 to 50 pounds

These should be mixed thoroughly. The best results will be obtained if applied while there is dew on the leaves.

1a. PARIS GREEN (WET).

Paris green .... 1 pound
Quicklime ....1 to 2 pounds
Water ....200 to 300 gallons

Slake the lime in part of the water; then add the Paris green slowly. Vary the strength according to the tenderness of the foliage. For tender growing peach and the like use 300 gallons of water.

2. LONDON PURPLE.

London purple	1 pound
Quicklime	2 to 3 pounds
Water	60 to 200 gallons

London purple is somewhat cheaper than Paris green, but its strength is variable and its use is therefore not to be recommended.

3. ARSENATE OF LEAD.

Acetate of lead (sugar of lead)	12 ounces
Arsenate of soda	4 ounces
Water	50 gallons

Put the arsenate of soda into a wooden bucket with 2 quarts of water. Put the acetate of lead into another bucket with 4 quarts of water. When these two are dissolved, mix well with the water and spray.

Arsenate of lead will not burn foliage, it mixes more readily and is held in suspension longer than Paris green. Prepared arsenate of lead is much more convenient. This comes in the form of a thick paste, which can be readily reduced to the proper strength. Arsenate of lead also comes as a powder, in which case it is dusted on at full strength or may be added to form a liquid spray.

3a. ARSENATE OF LEAD.

Arsenate of lead	2 to 5 pounds
Water	50 gallons

Arsenate of lead is also used with the Bordeaux mixture instead of the Paris green.

3b. ARSENATE OF LIME.

White arsenic	1 pound
Lime	2 pounds
Water	3 gallons

Boil together for fully 40 minutes after the boiling point is reached. As a precaution against danger of burning of foliage, slake an additional pound of lime, add to it three or four gallons of water, and add to the boiled mixture. Strain and dilute to from 200 to 250 gallons for hardy vegetation such as potatoes. Do not use at all on stone fruits or on cucurbits. Dilute to 300 to 400 gallons for tender vegetation.

4. HELLEBORE.

White hellebore	1 ounce
Water	2 gallons

The hellebore may be used without reducing.

5. RESIN LIME MIXTURE.

Pulverized resin	5 pounds
Concentrated lye	1 pound
Fish or animal oil	1 pint
Water	5 gallons

Place the oil, resin and 1 gallon of hot water in a kettle and heat till the resin softens; then add the lye and stir thoroughly; add 4 gallons of the hot water and boil till a little will mix with cold water and make a clear amber-colored solution. Add water to make 5 gallons. Keep this as a stock solution. For use take—

Water	16 gallons
Milk of lime	3 gallons
Paris green	¼ pound
Stock solution	1 gallon

The object of this preparation is to obtain an adhesive material which will cause the poison to adhere to smooth leaves, like those of cabbage and cauliflower.

6. GREEN ARSENOID.

This is an arsenical poison which is used by some persons instead of Paris green. It seems to remain in suspension longer than Paris green; yet its use is not general.

INSECTICIDES FOR SUCKING INSECTS

(Insects like plant lice, scale, squash bugs, etc.)

7. KEROSENE EMULSION.

Kerosene (coal oil)	2 gallons
Soap	½ pound
Water (soft)	1 gallon

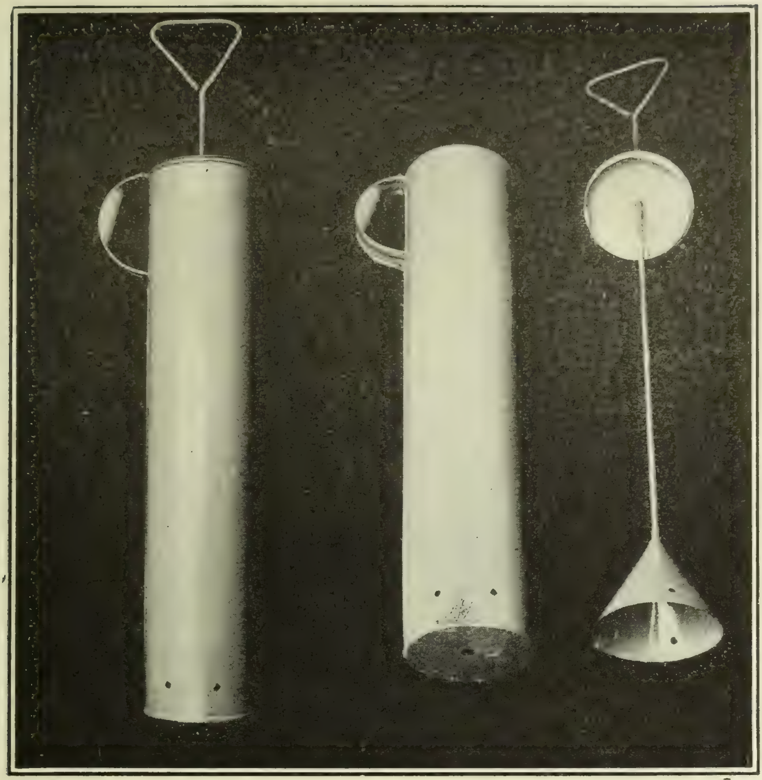
Dissolve the soap in water by boiling, remove from the fire, add kerosene, mix vigorously until all forms a creamy mass and emulsion. Dilute according to the per cent wanted.

For	10	per	cent	oil	emulsion	add	17	gallons	of water
"	15	"	"	"	"	"	10½	"	" "
"	20	"	"	"	"	"	7	"	" "
"	25	"	"	"	"	"	5	"	" "
"	30	"	"	"	"	"	4	"	" "
"	40	"	"	"	"	"	2	"	" "
"	50	"	"	"	"	"	1	"	" "

How to make an oil emulsion

In the making of an emulsion it is essential that the oil when added to the water be thoroughly agitated in order that a thorough mixing of the ingredients be obtained. This may be accomplished by turning the nozzle of the force pump into the mixture and forcing the solution through. The heat, however, is injurious to the valves of the pump. A jet of steam, if handy, could be used with good results. A simple device for making a perfect emulsion is one originated by Prof. H. A. Morgan, mentioned in Bulletin No. 48 (second series) of the Louisiana Agricultural Experiment Station, Baton Rouge, La.

It consists of a tin cylindrical vessel, 18 inches long and 4 inches in diameter, and a plunger or piston 22½ inches long, as shown on page 129 (A and B). About one inch from the lower end of the cylinder is a row of seven holes each ¼ inch in diameter. In the center of the bottom of the cyylinder is a single opening ½ inch in diameter. The plunger consists of a ¼ inch iron rod with tin cone 3½ inches high and of a circumference that will permit to fit nicely within the cylinder, as shown on page 129 (C.) This is firmly soldered on one end of the rod and a handle is fitted on the other. A row of five holes, each ¼ inch in diameter, is made ½ inch from the base of the cone. In the base is an



A B C

AN EMULSIFIER

opening ½ inch in diameter. The openings at the base of the cone may be increased in number and lessened in diameter. This hastens the operation of emulsifying but increases the labor. The above-described implement can be made by any tinsmith, and should not cost more than 35 or 40 cents.

7a. TREATMENT FOR TICKS, HORN FLIES, STABLE FLIES, ETC.

Cottonseed oil (fish oil may be substituted)	1 gallon
Sulphur	1 pound
Carbonate of potash	1 pound
Concentrated lye	3 ounces
Beeswax	½ pound
Zenoleum	1 pint
Water	3 gallons

Heat the cottonseed oil, sulphur, potash and beeswax until the beeswax is melted, then add 3 gallons of cottonseed oil or fish oil. To this add 1 pint of zenoleum or crude carbolic acid. Before applying this wash to cattle or horses dilute with equal parts of water thoroughly mixing it to form a good emulsion.

8. WHALE OIL SOAP SOLUTION.

Whale oil soap .... 1½ to 2 pounds
Hot water .... 1 gallon

Use this solution for late winter spray.

8a. WHALE OIL SOAP SOLUTION.

Whale oil soap .... ¼ pound
Hot water .... 1 gallon

Use for summer spray.

9. THE LIME-SULPHUR SOLUTIONS.

The sprays made from lime and sulphur may be divided into three heads, viz., the home-boiled, factory-boiled and self-boiled. The first two act both as fungicides and insecticides; the last only as a fungicide. All the lime-sulphur solutions have efficiency and cheapness which commend them highly.

HOME-BOILED LIME-SULPHUR SOLUTION

Home-boiled lime-sulphur may be made after many different formulas. The one which we have used with best success is made from

21 lbs. stone lime (burnt lime).
18 lbs. flour of sulphur.
50 gallons water.

Into the boiler, a kettle or tray (a barrel, or tank if steam is to be used), place five or six gallons of water; into this add the sulphur which has been passed through a flour sieve; then the lime, small quantity at a time. Fire should now be started under the boiler. After all the lime has been added and the slacking has finished, add water to keep to a good boiling consistency and boil vigorously for 40 to 60 minutes. The solution is now ready to be thinned and strained carefully into the spray tank or barrel; sufficient water being added to make 50 gallons of spray.

This spray is for winter, late fall or early spring use. Never use while leaves or buds are opening. Never put this solution into a copper tank or sprayer, for its action upon copper is rapid and will soon ruin a receptacle of this metal.

This winter spray is for San Jose scale, and leaf-curl. The above is known as home-boiled solution.

FACTORY-BOILED LIME-SULPHUR SOLUTION

A very similar solution can be obtained in concentrated form from factories, and is then known as the factory-boiled. This is usualy diluted with from 7 to 9 parts of water to make the winter spray. In barrel lots this sells for about $7.00 per barrel, making the cost about the same as that made at home. There are many reliable grades which are about as efficient as the home-boiled solution. If good lime cannot be obtained and the proper care given to making the solution, preference should be given to factory-boiled solution. At its present price and quality, the commercial lime-sulphur solution is to be recommended.

9a. THE SELF-BOILED LIME-SULPHUR SOLUTION.

The experiments with the self-boiled lime-sulphur solution for several years in different States have given results which highly commend this spray for the troubles which have heretofore been met with difficulty. Credit is due Mr. W. M. Scott, formerly Pathologist, Bureau of Plant Industry, Washington, D. C., for his preliminary experiments in 1907 and 1908. The following formula is from Bulletin 174, Bureau of Plant Industry, U. S. Department of Agriculture. The formula giving the best results is:

8 lbs. flour of sulphur
8 lbs. fresh lime (burnt)
50 gals. water

In making this mixture best results can be obtained by making a larger quantity—say four times this amount, as follows: To 8 or 10 gallons of water in a barrel add 32 pounds of fresh stone lime (the quicker acting lime the better) ; when the slacking begins add 32 pounds of fine sulphur which has been run through a sieve to break up all lumps. As the lime continues

to slake, water may be added to keep it from drying. The mixture should be constantly stirred until the slaking is over, when more water is added to stop the cooking. Strain and dilute to make 200 gallons of spray. Only a small amount of soluble sulphur should be present; the desired solution is a mechanical mixture of lime and sulphur. In straining the spray the coarse parts of the lime are to be taken out but the sulphur worked through the sieve.

HOW AND WHEN TO USE THIS SPRAY

The self-boiled lime-sulphur solution should be applied in the form of a fine spray by a pump equipped with a good agitator. The time for applying will be governed by the disease to be treated. The number of applications may be one, two, three or four times, according to conditions and objects sought.

In place of the self-boiled lime-sulphur solution made at home the commercial concentrated solution may be diluted for summer use. With peach this should be used experimentally. With apple the following reduction gives good results.

Hydrometer Reading in Baume Degrees of the Concentrated Lime-Sulphur Solution.	*Gallons of Water to Add to One Gallon of the Commercial Concentrated Lime-Sulphur Solution.*
35	45
34	43½
33	41¼
32	40
31	37½
30	36¼
29	34¼
28	32¾
27	31
26	29½
25	27¼

The lime-sulphur wash from the standpoint of cheapness, accessibility and efficiency is the best spray known for the San Jose Scale.

The time for applying the lime-sulphur wash is while the trees are dormant, as in the late fall, winter or early spring.

Prune the trees before spraying and do thorough spraying. If all parts of the trees cannot be covered at the first spraying repeat the process soon.

9b. SOLUBLE SULPHUR COMPOUND.

Fill the spray tank or barrel about two-thirds full of water. Then add the Soluble Sulphur Compound. If agitator is then started while you are filling the remainder of the tank, the Soluble Sulphur Compound will be dissolved very quickly in either hot or cold water.

If Arsenate of Lead is used in connection with the Soluble Sulphur Compound, it should be added last.

Direction for Winter Spraying.—Use 10 pounds of the dry Soluble Sulphur Compound to each 50 gallons of water, for the control of San Jose Scale, Oyster Shell Bark Louse, Pear Psylla, Peach Leaf Curl, and other sucking insects or fungous diseases, when trees are dormant.

Direction for Summer Spraying.—When trees are in foliage, for the control of Apple Scab and the larvae of sucking insects, use 1½ to 2 pounds of Soluble Sulphur Compound to 50 gallons of water.

10. TOBACCO INFUSION.

Tobacco (waste or stems) .... 1 pound
Boiling water .... 4 gallons

Add hot water or tobacco when cold, strain, and add 1 pound of whale oil soap or 2 pounds of soft soap to each 50 gallons of tobacco infusion.

10a. TOBACCO DUST.

Tobacco is effective against the root aphis when used freely upon the roots.

10b. "BLACK LEAF 40."

"Black leaf 40" ....½ to 1 pint
Water ....100 gallons

"Black Leaf 40" is a solution of nicotine sulphate, guaranteed under the National Insecticide Act to contain 40% nicotine. It is highly recommended as a spray for soft bodied sucking insects.

"Black Leaf 40" used alone or diluted according to directions neither burns nor stains orchard-foliage or fruit; nor does it clog the spray nozzles.

"Black Leaf 40" is effective as a spray for plant lice, thrips, leaf hoppers, etc., in orchard or garden.

11. CARBOLIC ACID EMULSION.

Soap	1 pound
Carbolic acid (crude)	1 pint
Water	1 gallon

Dissolve the soap in hot water, add carbolic acid, and churn vigorously until an emulsion is formed. Dilute with 30 parts of water.

12. PYRETHRUM POWDER (INSECT POWDER).

For spraying use—

Pyrethrum powder	1 ounce
Water	3 gallons

12a. PYRETHRUM POWDER (INSECT POWDER).

For dusting—

Mix thoroughly 1 part by weight of pyrethrum with 4 parts of flour. Keep in a close vessel for 24 hours before using.

13. LYE SULPHUR.

Sulphur (flowers)	20 pounds
Caustic soda	10 pounds

This spray is especially good for red spider. To the sulphur mixed with water to make a paste add the caustic soda. Add cold water to prevent burning. When cool, add water to make 20 gallons. This gives the stock solution. For use, add 50 gallons of water to 2 gallons of this stock solution.

14. SULPHUR.

Dry flowers of sulphur dusted upon moist leaves is an effective remedy for plant lice.

COMBINED INSECTICIDES AND FUNGICIDES

15. BORDEAUX MIXTURE AND PARIS GREEN.

Copper sulphate	4 pounds
Quicklime	6 pounds
Paris green	4 to 5 ounces
Water	40 to 50 gallons

15a. BORDEAUX MIXTURE AND ARSENATE OF LEAD.

Copper sulphate	4 pounds
Quicklime	6 pounds
Arsenate of lead	1½ pounds
Water	50 gallons

15b. BORDEAUX MIXTURE AND ARSENATE OF LIME.

Copper sulphate	4 pounds
Quicklime	6 pounds
Arsenate of lime	1½ quarts
Water	50 gallons

16. IVORY SOAP.

Ivory soap	1 pound
Water	15 gallons

Dissolve the soap in hot water and apply when warm.

17. BAIT FOR CUT WORMS.

Bran or middlings	40 pounds
Paris green	1 to 2 pounds

Add enough molasses to sweeten well; mix with water to make a thick mash. Spread around on the ground later in the evening. Keep fowls from this.

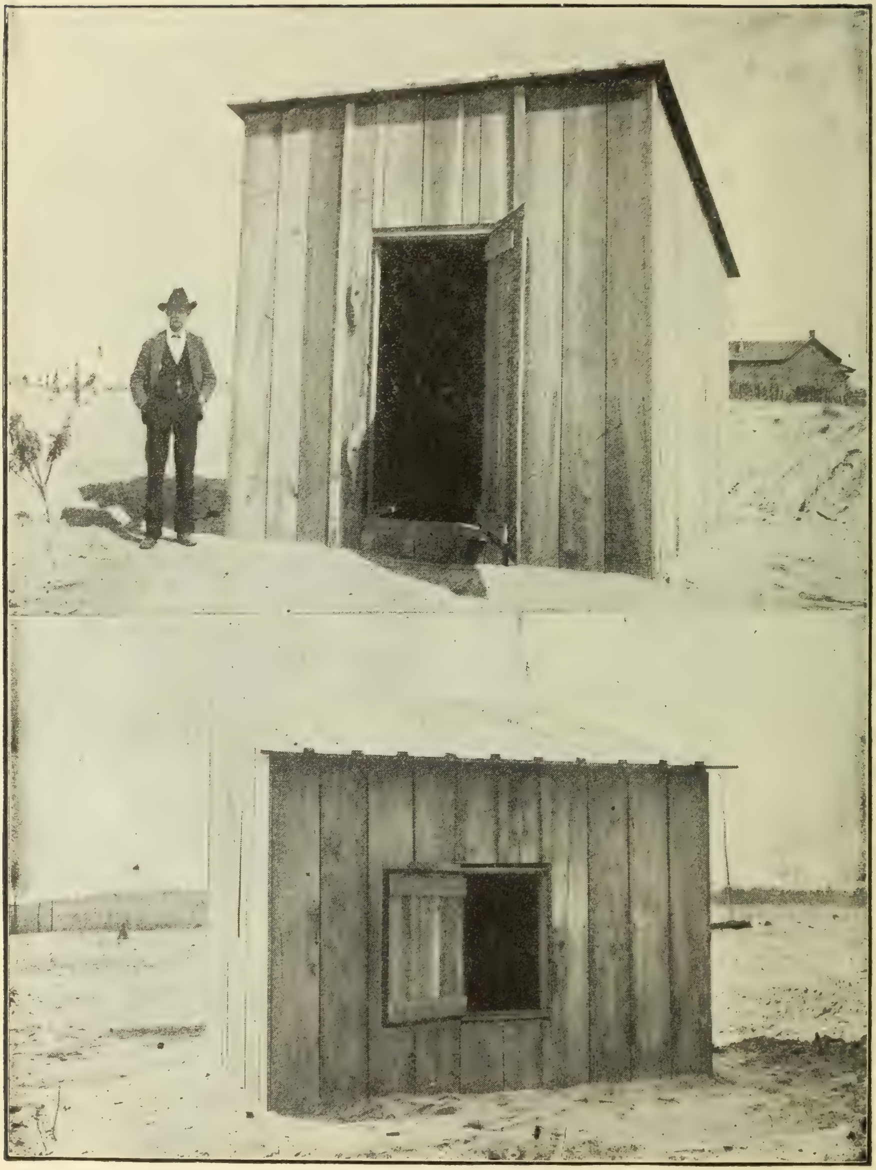
FOR FUMIGATING

18. HYDROCYANIC ACID GAS (STRONG).

Potassium cyanide	1 ounce
Sulphuric acid	2 ounces
Water	4 ounces

This charge is for 100 cubic feet.

For one or two-year-old apple, pear, plum and peach. Allow fumigation to continue for 40 minutes.



An Inexpensive Fumigator, Front and Rear Views.

18a. HYDROCYANIC ACID GAS (WEAK).

Potassium cyanide ....2-3 ounce
Sulphpric acid ....1½ ounces
Water .... 3 ounces

This charge is for 100 cubic feet.

For June buds, roses and budding and grafting wood. Allow fumigation to continue for 30 minutes.

Hydrocyanic acid gas is lighter than air, highly penerating, and a deadly poison. The enclosure in which this gas is used should be perfectly air-tight. Care should be taken to get the right chemicals for this fumigating, the cyanide to be fused 98 per cent, the sulphuric acid to be the best commercial, specific gravity 1.83. For more detail upon fumigation, see Bulletin No. 2 of the Tennessee State Board of Entomology, on The Fumigation of Nursery Stock.

18b. SODIUM CYANIDE.

Sodium cyanide is now being used as substitute for potassium cyanide—advantages being that it is cheaper and less poisonous to man.

19. CARBON BISULPHIDE.

5 pounds to 100 bushels of grain.

Leave in tightly closed bin for 24 hours.

1½ tablespoonfuls may be used for every 100 pounds.

The bisulphide may be thrown upon the grain, or it may be put into shallow dishes and set upon the grain. The gas is much heavier than air and sinks down through the grain, killing any insects that may be there.

Caution.—Carbon bisulphide is highly inflammable. Do not approach the enclosure containing this gas with a lantern, a lighted pipe, match or a cigar. When fumigation is over let the bin thoroughly ventilate. A trade name for carbon bisulphide is "Fuma."

The above is a dosage at ordinary temperature at 60 to 70 degrees Fahrenheit. At much lower temperature a much heavier dose will be required. At higher temperature one-half to three-fourths the amount will suffice.

19a. CARBON TETRACHLORIDE.

2 pounds to each 100 cubic feet.

This fumigant is non-explosive and may be used in place of carbon bisulphide, where there is possible danger of fire. It is slower in its action than carbon bisulphide.

20. SULPHUR.

Burn 6 ounces of sulphur in a space of 1,000 cubic feet. Keep closed for at least 12 hours.

21. NIKOTEEN.

Nikoteen	1-7 ounce
Water	5 ounces

Place this upon a hot steam pipe and let it vaporize at night. The amount given above is sufficient for a space of 1,000 cubic feet.

FUNGICIDES

22. SELF-BOILED LIME-SULPHUR SOLUTION.

Stone lime (burnt lime)	8 pounds
Sulphur (flour)	8 pounds
Water	50 gallons

22a. REGULAR BORDEAUX MIXTURE.

Copper sulphate (blue stone)	5 pounds
Quicklime (burnt lime)	5 pounds
Water	50 gallons

Dissolve the copper sulphate by suspending it in a bran bag or gunny sack in a wooden vessel containing 4 or 5 gallons of water. Slake good burnt lime in another vessel. When ready to use the Bordeaux mixture, add each of the above-mentioned solutions to two separate barrels, each diluted to make 25 gallons. These two solutions may now be added by pouring one into the other and thoroughly mixing. The result is 50 gallons of the Bordeaux mixture ready for use. This solution may be used on foliage not especially sensitive to copper.

22b. STRONG BORDEAUX MIXTURE.

Copper sulphate (blue stone	6 pounds
Quicklime (burnt lime)	4 pounds
Water	50 gallons

Separately the sulphate and the lime solutions may be kept for some time, but when these are mixed the solution should be used at once.

22c. WEAK BORDEAUX MIXTURE

Copper sulphate	2 pounds
Quicklime	2½ pounds
Water	50 gallons

Make according to the foregoing suggestion.

23. SODA BORDEAUX MIXTURE.

(For very late spraying.)

Copper sulphate	4 pounds
Commercial caustic soda	1½ pounds
Water to make	50 gallons

Dissolve and mix the copper sulphate and lye and dilute this solution with the water before using. This mixture is used instead of the ordinary Bordeaux, when a fungicide is needed within six weeks of the time the fruit is to be gathered, as it will not seriously spot it.

24. AMMONIACAL COPPER CARBONATE SOLUTION.

Copper carbonate	6 ounces
Ammonia	3 pints
Water	40 to 50 gallons

Dissolve copper carbonate in the ammonia. This may be kept in a jar or bottle tightly corked. When ready for use dilute with water.

25. COPPER SULPHATE SOLUTION.

Copper sulphate	4 pounds
Water to make	50 gallons

For use before the buds open, the above solution is fully as effectual as Bordeaux mixture, and is easier to prepare and apply. The weaker solution should be used upon the peach, although no injury would be done upon any kind of fruit tree, while in a dormant condition, if the stronger solution should be used, but *it should not be applied to any plant after the buds have opened.*

26. POTASSIUM SULPHIDE SOLUTION (LIVER OF SULPHUR).

Potassium sulphide	1 ounce
Hot water	2 to 3 gallons

Use as soon as it is cool.

27. FORMALIN SOLUTION (FOR OAT AND WHEAT SMUT).

Formalin (40% formaldehyde gas).....	1 pint
Water	50 gallons

Soak the grain in this mixture for one hour and a half, spread out to become partially dry before sowing.

27a. FORMALIN SOLUTION (FOR POTATO SCAB).

Formalin	16 ounces
Water	30 gallons

Before cutting potatoes for planting, place them in a sack and soak them two hours in the above mixture.

28. CORROSIVE SUBLIMATE SOLUTION (FOR POTATO SCAB).

Corrosive sublimate	2 ounces
Water	15 gallons

Dissolve the corrosive sublimate in 2 gallons of hot water and dilute to make 15 gallons. Soak potatoes in solution for 1½ hours before cutting them.

28a. CORROSIVE SUBLIMATE SOLUTION (FOR CARRAGE SEED).

Corrosive sublimate	1 part
Water	1000 parts

Soak seed in this solution for 15 minutes. Black rot may be introduced on cabbage seed. It is advisable to soak seed as above.

SPRAYING TO KILL WEEDS

IN LAWNS, PARKS, PASTURES, HAY AND GRAIN CROPS

Spraying with the herbicides given can be used to destroy such weeds as mustard, dandelion, oxeye daisy, white-top, thistle, carrot, parsnips, elders, poison-ivy, ragweed, and all broad-leaved weeds. These sprays will leave narrow-leaved crops such as blue grass, timothy, red-top, and other grasses, including the growing cereal grains—wheat, oats, rye, etc., without injury if properly adapted in strength and time of application.

The time of applying the sprays has to be adjusted to the condition of the crop and the relative development of the weeds. The first spraying should be made not later than the beginning of the bloom, and repeated applications should be made as new leaves are developed, provided the condition of the host crop will permit it. In grain fields, the best results with a single spraying will be obtained on most weeds by applying the spray just as the crop is ready to occupy the land.

Timothy and other grass meadows should be sprayed just before the grass begins heading out.

There are several solutions which may be used, but in general, common salt and iron sulphate solutions are found most satisfactory. They are effective in killing the more common weeds and are not dangerous to stock in pastures in which they may be used.

HERBICIDES

29. COMMON SALT SOLUTION.

Common salt	150 pounds
Water	50 gallons

Should be applied at the rate of 50 to 75 gallons per acre sprayed. Useful for killing Canada thistle, dandelion, poison-ivy, yarrow, horse nettle, etc.

30. IRON SULPHATE SOLUTION.

Iron sulphate (copperas)	100 pounds
Water	52 gallons

Should be applied at the rate of 50 to 75 gallons per acre. Good to kill mustard, ragweed, white-top, yarrow, and other broad-leaved weeds in field of growing grain or timothy.

LIST OF PLANTS AND REMEDIES FOR PESTS ATTACKING THEM

Apple.—For codling moth, canker worm, fall web worm, tent caterpillar and tussock moth, use arsenate of lead or Paris green. For fungous diseases, use the strong Bordeaux mixture or self-boiled lime sulphur solution.

For oyster-shell scale and scurfy scale, use 15 per cent kerosene emulsion.

For San Jose scale, use lime-sulphur solution, either formula under 9.

Apricot.—Same treatment as for peach and plum.

Asparagus.—For beetle, spray with arsenate of lead after you have stopped cutting; during the spring pyrethrum powder may be dusted on the larvae.

For rust, spray during July and August with the Bordeaux mixture.

Bean.—For rust or anthracnose, spray with the Bordeaux mixture every ten days.

Blackberry.—For fungous attacks, use Bordeaux mixture or copper sulphate solution before the buds open.

For insect attacks, use Bordeaux mixture and Paris green or Bordeaux and arsenate of lead, just before the flowers open and just after the bloom has fallen.

Cabbage.—For clubroot, rotate crop or lime the soil at the rate of 35 to 50 bushels per acre.

For lice, use 10 per cent kerosene emulsion.

For cabbage worms, use Paris green when the plants are young; when the plants begin to head use hellebore.

For Harlequin bug, use a trap crop; when this is thickly infested spray with pure kerosene.

Cauliflower.—Same as cabbage.

Celery.—For rust and blight, use Bordeaux every ten days or two weeks.

Cherry.—Same treatment as for plum.

Chrysanthemum.—For blight, use Bordeaux mixture. Repeat every ten days or two weeks.

Corn.—For wire worms, rotate crops and practice fall plowing.

For the weevil in the bins, fumigate with the carbon bisulphide.

For red spider, use the lye-sulphur wash.

Cotton.—For red spider, use the lye-sulphur wash.

For lice, use 10 per cent kerosene emulsion.

For the caterpillar, use Paris green, or arsenate of lead, either wet or dry.

Cucumber.—For the blight, use Bordeaux mixture.

For the beetle, use Bordeaux mixture and the arsenate of lead or Paris green.

For lice, use 10 per cent kerosene emulsion.

Currant.—For the worm, use Bordeaux mixture and the arsenate of lead before fruit is nearly grown. After this time use hellebore.

Dewberry.—Same treatment as for the blackberry.

Elm.—For the beetle, use arsenate of lead.

Gooseberry.—Same treatment as for the currant.

Grape.—For rot and mildew or anthracnose, use Bordeaux mixture.

For the aphis, use 15 per cent kerosene emulsion.

For the flea beetle, use Paris green or arsenate of lead.

For fungous diseases, use the Bordeaux mixture.

For the root worm, use arsenate of lead at the rate of 4 pounds to 50 gallons of water.

Greenhouse.—For the thrips, use nikoteen, 1-7 ounce; water, 5 ounces. See formula No. 21.

For the white fly, use hydrocyanic acid gas according to formula No. 18, diluted to from 1-10 to 1-20 that strength, according to the tenderness of the plants and the condition of the house.

Lettuce.—For the aphis, use the tobacco infusion, or "Black leaf 40."

Muskmellon.—Same treatment as for the cucumber.

Nectarine.—Same treatment as for the peach.

Nursery stock.—For the San Jose scale, burn when infested; fumigate with hydrocyanic acid gas.

For the aphis, use 15 per cent kerosene emulsion.

For fungous diseases, use the Bordeaux mixture, or self-boiled lime-sulphur.

Oats—For the smut, use formalin.

Onion.—For the root maggot, use carbon bisulphide in the ground.

Pear.—For the pear blight, cut out below the affected region and burn.

For the psylla, use 15 per cent kerosene emulsion.

For scale and fungus, same as treatment on apple.

Peach.—Same treatment as for the plum. The foliage is very tender, and consequently liable to burn with Paris green or the poorly made Bordeaux. Arsenate of lead is better. Use self-boiled lime-sulphur solution instead of Bordeaux.

Plum.—For black knot, prune and burn. Spray before the buds open with Bordeaux mixture.

For brown rot, thin fruit and spray early with the lime-sulphur solution.

For the leaf blight, shot-hole fungus, use weak Bordeaux.

For the curculio, use Paris green or arsenate of lead. The jarring method is also practiced successfully.

For the scale insects, notice treatments for the apple.

Potato (Irish).—For the scab, use formalin or corroisve sublimate.

For the beetle, use Bordeaux and arsenate of lead or Paris green.

Quince.—For the scale, same treatments as for the apple.

For the fungous diseases, use Bordeaux mixture.

Raspberry.—Same treatment as for the blackberry.

Rose.—For the mildew, use sulphide of potassium.

For the aphis, use the 15 per cent kerosene emulsion.

For the chaffer, use arsenate at the rate of 4 pounds to 50 gallons of water.

For the slug, use hellebore, Paris green, tobacco or "Black leaf 40."

Strawberry.—For the fungous diseases, use the Bordeaux mixture.

Tobacco.—For the horn worm, use arsenate of lead or Paris green.

For the cut worms, use poison mash or arsenate of lead on clover.

For the cigarette beetle, use carbon bisulphide.

Tomato.—For the rot, use Bordeaux mixture, and repeat every ten days or two weeks if necessary.

Watermelon.—Same treatment as for the cucumber.

Wheat.—For smut, use formalin.

NOTES OF PRACTICAL INTEREST TO FARMERS AND FRUIT GROWERS ON THE SUBJECT OF SPRAYING

All chemicals used in spraying should be kept correctly labeled and out of reach of children.

Never spray when the trees are in bloom. Such practice will injure developing fruit and kill the bees, which are necessary for fertilization. Spray before the buds open and just after the bloom has fallen. The strong lime-sulphur solution is most effective in February and March.

In all the formulas which require quicklime, the best stone lime freshly burned should be used. Air-slaked lime will not answer.

When hydrocyanic acid gas is used, fully fifteen minutes should be allowed for ventilating the enclosure after the fumigation is over. This gas being a deadly poison, all precautions against breathing it should be taken.

Bordeaux mixture should be applied several times, once before the buds break, once after the bloom falls, then after a lapse of ten days or two weeks. A fourth application may be made a week later. With some fungous diseases Bordeaux may be profitably used every ten days to two weeks. If the lime-sulphur wash has been used the first application of the Bordeaux may be omitted.

Information about insects and insect pests and fungous diseases will be gladly furnished if specimens of insects and their work be sent to us. Place specimens in a box, wrap neatly and put your name and address somewhere upon the package. In an accompanying letter tell us all you have noticed about the insect or disease, its first appearance, rapidity of increase, extent of destruction, etc.

Never put the strong lime-sulphur solution in a copper sprayer. The chemical action between the copper and the solution is rapid, and does great injury to the sprayer. When using the lime-sulphur solution a galvanized iron or wooden receptacle is to be used.

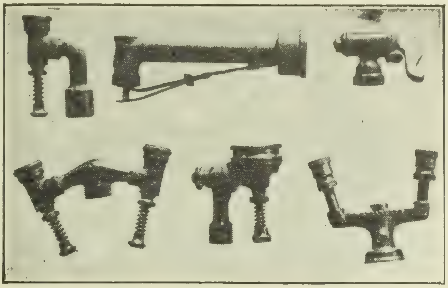
In spraying, great care should be taken to cover all parts of the tree, shrub or plant. If a heavy rain immediately follows your application of a spray, the work should be done over. Do not spray when the foliage is wet.

Before spraying it is best to prune the trees in order to economize in the surface to be covered by the spray; also to rid the trees of their worst affected limbs. Burn the wood removed. Prune out the scale-affected branches, the dead wood, and the undesirable water sprouts. With the peach tree new wood should make up the major part of the tree. An ideal spray day is a quiet, bright one, when the air is dry and cool.

Study spray formulas, and the different makes of spray pumps and nozzles, that you may select the best for you conditions.

Spraying machines

Spraying machines are as much a part of modern orchard and garden tools as pruning shears and cultivators. There is not an orchard, garden or farm that would not be better for their use. Indeed, in some cases it is almost a question of abandoning the cultivation of certain crops for the want of spraying machines for their protection. It is quite feasible for neighbors to co-operate in the purchase of an outfit.



A COLLECTION OF STANDARD NOZZLES.

He who does not spray from this time on will be left behind in the race for success in the market, and his supply of fruits will be deficient in both quantity and quality. There are those who have taken advantage of the aids to practical horticulture, and their fruits are known in the market as being clean, smooth and sound. Everyone knows how poor a chance for sale wormy, knotty or scabby fruit has beside that which is nearly perfect.

Spray for success

Coming from good authority is the statement that the codling moth, the principal source of wormy apples, is responsible for the annual loss in the United States of $12,000,000 in fruit and an expenditure of $3,000,000 to $4,000,000 for sprays and the labor required for their application, and along with this statement comes the encouraging news that the use of arsenical sprays saves from 90 to 95 per cent of the apple crop.

Shade tree spraying

The shade trees in many of the Southern towns and cities are rapidly being killed by preventable scale insects. Especially fond are these insects of the maple and elm trees. They multiply rapidly, and soon crust over the entire surface. These scale insects appear on the bodies as well as the larger and smaller branches. The first appearance of

the injury will be noticed by the dying of the terminal branches. This shade tree insect is commonly known as the gloomy scale, and may be controlled by spraying with 25% kerosene emulsion. The difficulty in spraying large trees is in the sprayer for doing efficient work. Hand sprayers may be used, equipped with extension rods and ladders for climbing up into the tree, but power sprayers are to be preferred. The tree should be sprayed thoroughly from top to bottom, every portion being reached by the spray. February and March are two of the best months for applying this spray. The cold winter weather has weakened and killed many of the adult scale, the bodies of which have flaked off, exposing the younger scale, which can readily be reached by a spray at this time of the year. The 25% kerosene emulsion is too strong a solution to apply to many of the trees while they are in leaf. With the leaves present also it would be impossible to do thorough spraying. Calling the attention of your town or city officials to this preventable loss might be the means of preserving the beauty of your city. As injury is rapidly increasing, early steps should be taken to prevent this loss.

How pruning and spraying paid

In one of the recent meetings of a State horticultural society, experiences were called for illustrating the value of pruning and spraying. The following figures were given by one who had harvested an average yield of 750 bushels of apples from his 550 trees. In 1912 this orchard was pruned and sprayed, and yielded 4,200 bushels of sound fruit and 2,000 bushels of average bulk apples, the crop netting $1,670. In 1913, a rather unfavorable year on account of drought, the yield was good, and the orchard produced $3,386 worth of apples, or an average of $6.00 per tree, or $300.00 to the acre. Another experience was given of a man with an orchard of 720 trees. He bought a power sprayer and sprayed the orchard carefully in the early spring, with the result that the income from his orchard was increased from $1,069.00 to $2,900.00. These are only two examples of what has been done by those who have given attention to pruning and spraying.

Just as great success awaits any orchardist in Tennessee who directs his attention to these important orchard practices.

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Agricultural Experiment Station

OF THE

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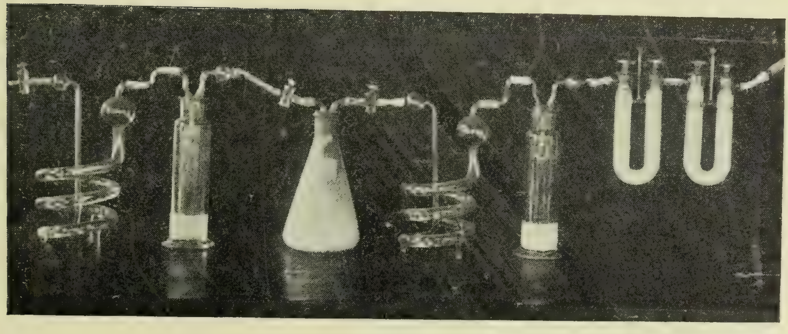
THE NON-EXISTENCE OF MAGNESIUM CARBONATE IN HUMID SOILS

BY

W. H. MACINTIRE

ASSISTED BY

L. G. WILLIS AND J. I. HARDY



APPARATUS FOR MEASURING DECOMPOSITION OF SOIL CARBONATES

KNOXVILLE, TENNESSEE

The Agricultural Experiment Station

OF THE UNIVERSITY OF TENNESSEE

The Experiment Station building, containing the offices and laboratories, and the plant house and part of the Horticultural Department, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy building, etc., are located one mile west of the University on the Kingston Pike. The fruit farm is adjacent to the Industrial School and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

THE NON-EXISTENCE OF MAGNESIUM CARBONATE IN HUMID SOILS

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PART I

BASKET AND RIM STUDIES

INTRODUCTION

The investigations reported in this bulletin seem to warrant the conclusion that magnesium carbonate does not exist as a solid mineral component of soils of humid climates, because of inhibitory conditions; and that the supposed existence of native magnesium carbonate, analogous to that of calcium carbonate in virgin soils, is an unproved assumption rather than an established fact. The research further shows that excessive amounts of magnesium carbonate applied to soils as precipitated carbonate, dolomite, and magnesite are soon decomposed, due to the great affinity of magnesia for silica, acid silicates and titanium oxide.

The experiments were begun in the spring of 1912, and involved a study of the factors influencing lime-requirement determinations, three distinct types of soil being used in the study. The work was planned with a view of determining the value of the Veitch-method results[1] when applied to field practice, and the laboratory studies were to be supplemented by extensive basket and pot experiments.

PLAN OF ORIGINAL EXPERIMENTS

The soils selected for study were, a Cumberland loam showing a Veitch lime requirement of 3812 pounds of CaO per 3,500,000 pounds of soil, a Tellico fine sandy loam showing a need of 1061 pounds of CaO per 3,500,000 pounds of soil, and a silt loam of Chickamauga limestone origin showing a requirement of 1346 pounds CaO for 3,500,000 pounds of soil, moisture-free basis being used in the calculations given. The treatments consisted of applications of Kahlbaum's "C. P." calcium carbonate, as follows: (1) the amount indicated by the Veitch method; (2) the Veitch-method indication augmented

by one-third; (3) the Veitch-method indication plus 1785 pounds; and (4) the Veitch-method indication plus 16,070 pounds. The carbonate was well mixed with the soils and placed in paraffined wire baskets[2] in the open, but sheltered from storms by a canvas cover. In the basket work, three crops were chosen—wheat, common red clover, and clover resistant to anthracnose[3]. Three check baskets uere used for each crop and soil, and three baskets for each crop and treatment of each of the three soils. Due to the excessive temperatures, the wire baskets were found to be impracticable for summer work, and the baskets were replaced by pots for the clover, the growth of which will be reported later.

Because of the enormous deposits of dolomite in Tennessee and the cheapness of the material, which is used extensively, the relative value of magnesium carbonate and its effect when applied to soils are of great importance. Accordingly, the procedure outlined for calcium carbonate was duplicated by using Kahlbaum's "C. P." normal magnesium carbonate, in amounts chemically equivalent to the calcium carbonate treatments.

Gardner and Brown[4] found after growing two clover crops in soils which had been treated with amounts of limestone sufficient to meet the requirements indicated by the Veitch method, that lime-requirement determinations subsequent to the clover crops indicated that the original Veitch-method requirement had been but 72 per cent satisfied by the limestone treatment.

In order to control the possible interfering factor of root growth, portions of the soils receiving various treatments were left exposed without cropping for one year. At the expiration of this period the fallow soils which had received the excessive treatment of calcium and magnesium carbonates were analyzed for carbonate CO_2 by the method described by MacIntire and Willis[5] and it was found that well within the limit of laboratory error, the excessive applications of magnesium carbonate had been entirely decomposed with dissipation of the CO_2 by simple contact with the fallow soils, which were protected from loss by leaching. Boiling for one minute with 1-15 phosphoric acid and applying the boiling blank of the untreated original soil, confirmed the results by the method cited. The residues of calcium carbonate and the dissipation of magnesium carbonate, in terms of calcium carbonate, are given in Table I.

The differences between the amounts of precipitated calcium carbonate actually decomposed and the amounts indicated by the Veitch method as needed to neutralize soil acidity are shown in Tables XIII, XIV and XV to be due to continued activity of precipitated calcium carbonate upon clays and other siliceous compounds, during long periods of contact without leaching, even after attaining strongly alkaline conditions. However, the decomposition of calcium carbonate falls far short of that produced in treatments of magnesium carbonate.

TABLE I—*Residual carbonates in soils treated with calcium carbonate as contrasted with the decomposition and the dissipation of the CO_2 of chemically equivalent amounts of magnesium carbonate—period of contact, 1 year*

Soil type	Wt. of soil m. f. basis	$MgCO_3$ indicated by the Veitch method to neutralize soil acidity	C. P. $MgCO_3$ applied	Carbonate CO_2 in $MgCO_3$-treated soils at end of 1 year	Carbonate CO_2 blank on original acid soil	Difference representing increase of carbonate CO_2 from treatment of $MgCO_3$	$MgCO_3$ increase calculated from CO_2 analyses	$MgCO_3$ applied in excess of the Veitch-method requirement	$MgCO_3$ lost by decomposition, excess above Veitch requirement	$MgCO_3$ loss above Veitch-method requirement = lbs. per A — 3,500,000 lbs. of soil	$MgCO_3$ loss above Veitch-method requirement in terms of $CaCO_3$ lbs. per A — 3,500,000 lbs. of soil
	Grams a	Grams	Grams	Per cent	Per cent	Per cent	Grams	Grams b	Grams		
Loam	28312	39.5878	142.4001	.0277	.0285	—.0008	—.2065	102.8123	103.0188	12740	15166
Sandy L'm	29920	11.6836	115.2735	.0223	.0148	.0075	2.2440	103.5899	101.3459	11855	14113
Silty Loam	25501	14.4166	120.3256	.0287	.0200	.0077	2.2186	105.9090	103.6904	14227	16937
Average										12941	15405

Residual carbonate CO_2 from $CaCO_3$ c treatments

Soil type	Wt. of soil m. f. basis	$CaCO_3$ indicated by the Veitch method to neutralize soil acidity	C. P. $CaCO_3$ applied	Carbonate CO_2 in $CaCO_3$-treated soils at end of 1 year	CO_2 blank on original acid soil	Difference representing residue of carbonate CO_2 from $CaCO_3$ treatment	$CaCO_3$ residue calculated from CO_2 analyses	$CaCO_3$ applied in excess of the Veitch-method requirement	$CaCO_3$ lost by contact in excess of Veitch-method requirem'nt during 1 yr. period	$CaCO_3$ residue = lbs. per 3,500,000 of soil	Difference between loss of $MgCO_3$ and increase of $CaCO_3$ in terms of $CaCO_3$ lbs. per 3,500,000 of soil
	Grams a	Grams	Grams	Per cent	Per cent	Per cent	Grams	Grams b	Grams		
Loam	28312	46.9918	169.0326	.1704	.0285	.1419	91.3061	122.0408	30.7347	11288	26454
Sandy L'm	29920	13.8688	136.8326	.1397	.0148	.1249	85.1591	122.9638	37.8047	9961	24074
Silty loam	25501	17.1129	142.8296	.0957	.0200	.0757	43.8734	125.7167	81.8433	6143	23080
Average										9131	24536

a All calculations on moisture-free basis.
b Variations in amounts of carbonate used in excess are due to moisture at time of treatments.
c Kahlbaum's moisture-freed carbonates used.

TABLE II—*Wheat crops grown upon soils of Table I—Average of 3 baskets of each treatment on each soil*

Calcium carbonate treatments

Type of soil	No lime		Veitch-method indication		Veitch + 1-3		Veitch + 1785 lbs. $CaCO_3$ per A.		Veitch + 16070 lbs. $CaCO_3$ per A.	
	Green wt. Grams	M. F. wt. Grams	Green wt. Grams	M. F. wt. Grams	Green wt. Grams	M. F. wt. Grams	Green wt. Grams	M. F. wt. Grams	Green wt. Grams	M. F. wt. Grams
Loam	8.3165	1.5851	7.5897	1.3943	12.2786	2.2141	10.1301	1.7963	10.7935	1.6797
Silty loam	8.3974	2.1636	9.6762	2.5629	10.2303	2.3654	8.8323	2.2148	11.4773	2.3100
Sandy loam	16.2557	4.0649	20.0540	4.4463	20.8951	5.2933	23.9595	6.0634	30.2400	7.7355
Average 3 soils, 9 baskets	10.9899	2.6045	12.4399	2.8012	14.4680	3.2909	14.3073	3.3582	17.5036	3.9084

Magnesium carbonate chemically equivalent to $CaCO_3$ treatments

Type of soil	No lime		Veitch-method indication		Veitch + 1-3		Veitch + = 1785 lbs. $CaCO_3$ per A.		Veitch + = 16070 lbs. $CaCO_3$ per A.	
	Green wt. Grams	M. F. wt. Grams	Green wt. Grams	M. F. wt. Grams	Green wt. Grams	M. F. wt. Grams	Green wt. Grams	M. F. wt. Grams	Green wt. Grams	M. F. wt. Grams
Loam	8.3165	1.5851	9.7871	1.7025	8.3391	1.5829	10.9792	1.9086	3.4053	.7432
Silty loam	8.3974	2.1636	9.1349	2.2745	10.9109	2.5955	9.7620	2.3574	1.6581	.6829
Sandy loam	16.2557	4.0649	22.8715	6.2952	23.7871	6.1477	18.1945	5.1093	6.2412	2.3706
Average 3 soils, 9 baskets	10.9899	2.6045	13.9312	3.4241	14.3457	3.4420	12.9786	3.1251	3.7682	1.2656

Plate 1—Growth of Wheat on the Carbonate-treated Sandy Loam of Table I

Check	V	V	V	V	V	V	V	V
		+	+	+		+	+	+
		1-3	1768	16070		1-3	1768	16070
	CaCO$_3$				MgCO$_3$			

V—Lime requirement by the Veitch method. Numbers represent pounds per acre 3,500,000 pounds of soil. Crops sown Oct. 8, 1912; harvested Feb. 12, 1913. Magnesium-carbonate-treated baskets are devoid of any residual carbonates.

EFFECTS OF TREATMENT OF THE TWO PRECIPITATED CARBONATES UPON GROWTH OF WHEAT

The three soils treated as outlined with both calcium and magnesium carbonates were seeded to wheat 10 weeks after the addition of the carbonates, the growths being shown by figures of Table II. It will be noted that the average increase in growth resulting from the three treatments of calcium carbonate, other than the excessive amount, upon the three soils, is not quite so great as that from the three corresponding treatments of magnesium carbonate. The smallest of these three treatments of the carbonates is fully equivalent to the amounts applied in average agricultural practice in this State.

REPETITION OF THE CARBONATE TREATMENTS UNDER FIELD CONDITIONS, WITH MORE EXTENDED COMPARISONS

In another set of experiments the work was substantiated under field conditions. In these experiments iron rims 11 inches deep, 3 inches being above ground, equivalent in area to 1-10,000 of an acre, were used as containers for 200 pounds each of moisture-free soil, giving a soil depth of 8 inches. The original surface soil was removed and the rims were placed. The transported soil selected for study was mixed with the various treatments and laid in the rims upon the undisturbed red clay subsoil. Using growth of clover in previous field trials upon the same soil as an indication of lime requirement, instead of determinations by the Veitch method, high-grade analyzed burnt lime to the amount of 8 tons per acre was applied and thoroughly mixed in the upper 6 inches of the soil of four rims. Hydrated lime treatments were also made in quadruplicate, while precipitated calcium carbonate applications were made in duplicate. Precipitated magnesium carbonate, ground dolomite, and ground limestone were each applied in two quadruplicate sets, each treatment of each rim being chemically equivalent to the burnt lime applied as determined by analyses. The hydrate and various carbonate treatments were applied and mixed with the soil in the same manner as the burnt lime.

In applying the treatments great care was taken to make very uniform and thorough mixtures of the treatments with the soil in order that the samples subsequently taken for analysis might be truly representative.

Treatments of burnt and hydrated lime are not strictly comparable with ground limestone, because of the great difference in fineness, and for this reason the introduction of precipitated carbonate enhances the opportunity for comparisons between the caustic and neutral forms of lime. The "C. P." precipitated magnesium carbonate used was analyzed and found to correspond in composition to the

TABLE III—*Residual carbonates from treatments of various forms of lime and magnesium carbonate as determined by analyses upon newly-sampled moist loam soil. Contact period under field conditions, 8 weeks*

Lab. No.	Rim No.	Weig't of soil in each rim	Treatments = 28180 lbs. $CaCO_3$ per A.			Carbonate CO_2 from analysis of original unlimed soil	Carbonate CO_2 found by analysis at end of 8 weeks, m. f. basis	Carbonate CO_2 gain over original soil	Carbonate CO_2 gain calculated to $CaCO_3$ grams per rim	Carbonate CO_2 gain over original soil in terms of $CaCO_3$ lbs. per A. 2,000,000 of soil	Average gain of $CaCO_3$ from lime treatments. lbs. per A. 2,000,000 of soil
			Moisture conditions	Form of added substance	Weight of treatments per rim						
		Grams			Grams	Per cent	Per cent	Per cent			
2701	L 19	90720	No rain	CaO a	725.76	.0322 e	.4564	.4242	874.6136	19282	
2702	L 20	"	" "	$Ca(OH)_2$ b	976.94	"	.4547	.4225	871.1182	19204	
2704	L 25	"	" "	CaO	725.76	"	.4376	.4054	835.8611	18426	
2705	L 26	"	" "	$Ca(OH)_2$	976.94	"	.4377	.4055	836.0673	18432	
2706	L 27	"	" "	$CaCO_3$ c	1295.68	"	.4562	.4240	874.9944	19290	
2717	M 19	"	Rain and watered	CaO	725.76	"	.4440	.4118	849.0567	18718	19170
2718	M 20	"	" "	$Ca(OH)_2$	976.94	"	.4706	.4384	909.0109	20040	
2720	M 25	"	" "	CaO	725.76	"	.4612	.4290	884.5201	19500	
2721	M 26	"	" "	$Ca(OH)_2$	976.94	"	.4415	.4093	843.9022	18604	
2722	M 27	"	" "	$CaCO_3$	1295.68	"	.4768	.4446	916.6348	20208	
2707	L 32	"	No rain	$MgCO_3$ d	1238.07	"	.0337	.0015	3.0906	68	Average residue of $MgCO_3$ from precipitated carbonate treatments in equivalence of $CaCO_3$ lbs. per A. 2,000,000 of soil. (A) Moist samples, m. f. basis ......541 (B) By boiling composite air-dri'd spls. o
2723	M 32	"	rain and watered	"	"	"	.0354	.0032	6.5923	143	
2910	L 31	"	No rain	"	"	"	.0337	.0015	3.0906	68	
2912	M 31	"	Rain and watered	"	"	"	.0402	.0080	16.4821	363	
2908	K 31	"	Exposed	"	"	"	.0532	.0210	43.2683	954	
2909	K 32	"	"	"	"	"	.0474	.0152	31.3077	690	
2914	N 31	"	"	"	"	"	.0573	.0251	53.7763	1154	
2915	N 32	"	"	"	"	"	.0518	.0196	40.3941	890	
Difference between residues of carbonate CO_2 from $CaCO_3$ and $MgCO_3$ treatments, representing affinity of MgO for SiO_2, in terms of $CaCO_3$ lbs. per A 2,000,000 of soil.											(A) 18624 (B) 19170

a 97.92 per cent CaO.
b Made by slaking the analyzed burnt lime.
c 89.15 per cent $CaCO_3$ by analysis.
d Analysis gave $(MgCO_3)_4.Mg(OH)_2.5\,H_2O$ as composition of precipitated carbonate.
e Average 2 rims, 4 determinations.

formula $(MgCO_3)_4$, $Mg(OH)_2$. 5 (H_2O) and computations from this analysis, assuming conversion of the hydrate to carbonate or its direct activity in correcting soil acidity, reduce the treatment of 1238.07 grams per rim to 1082.97 grams of normal carbonate. In the rim experiments the Cumberland loam of Table I was used and the soil of 8 rims was treated with the excessive applications of magnesium carbonate, equivalent in each case to 28,180 pounds of $CaCO_3$ per 2,000,000 of soil, 4 rims receiving carbonate alone and 4 receiving a supplementary treatment of barnyard manure. Four rims, 2 treated with magnesium carbonate alone and 2 with magnesium carbonate plus manure, were exposed to weather conditions during the experiment, the rainfall of 6 inches during June, July and August being uniformly distributed in showers and insufficient to cause any leaching during the 8 weeks' interval between treatment and sampling for CO_2 analyses. Two rims, one with magnesium carbonate alone and one with barnyard manure supplementary to the carbonate treatment, were protected from any rainfall, and 2 more, one of each treatment, were exposed to the weather and furnished with additional water to the extent of 8 inches, amounting to 14 inches in all, applied at various intervals in quantities insufficient, however, to cause leaching. The soil when placed in the rims contained 15.8 per cent moisture. When first applied the magnesium carbonate was in such bulk as to give to the soil a decidedly whitish appearance, which persisted for some days. On sampling at the end of 8 weeks, very minute white specks could be noticed throughout the soil treated with calcium carbonate, while no evidence of the presence of the more bulky magnesium carbonate could be noted. In Table III are given the results of the analyses, which were made in duplicate upon newly taken moist samples. The results were checked within a limit of error of .002 gram, in the aggregate increase of weight of the tubes used for collection of the gas, 25-gram charges of soil being used in the analyses.

DISCUSSION OF RESULTS OF TABLE III

Though it may be assumed that the analyses of the moist samples given in Table III mean that there actually exist in the treated soils minute amounts of residual magnesium carbonate still undecomposed at the end of 8 weeks, it should be emphasized that the limit of error, .002 gram, in weighing 2 tubes amounts to .008 per cent, which is increased to about .01 per cent on conversion of the results of the moist soil to the moisture-free basis. The possible slight occurrences of CO_2 in the soil moisture of the fertile loam are also included in the estimations. The writer believes, however that agricultural chemists familiar with the routine of the analyses would consider the entire set of magnesium-carbonate-treatment CO_2 determinations as within the limit of error and as checking the untreated soil. Samples of the untreated and originally thoroughly mixed soil in the same experi-

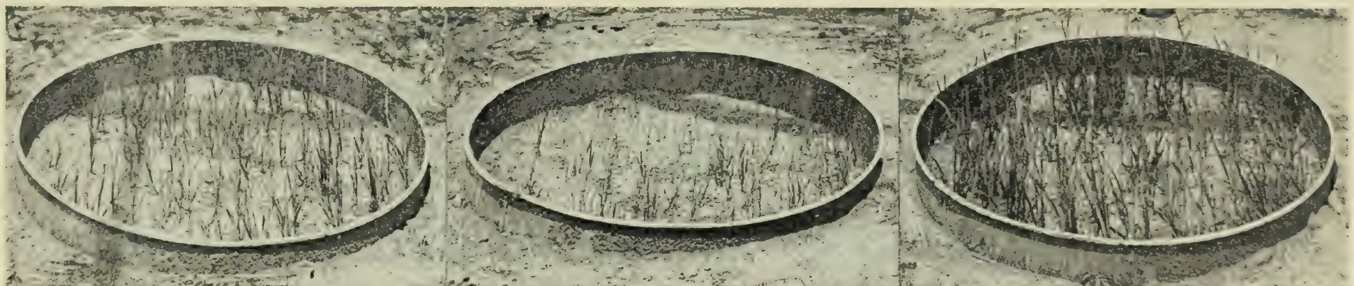
PLATE 2—COMPARISON BETWEEN THE EFFECTS OF PRECIPITATED CALCIUM AND MAGNESIUM CARBONATES UPON TALL OAT GRASS

No carbonates in $MgCO_3$-treated soil at time of seeding

$CaCO_3$
28,180 lbs. per 2,000,000 of soil

$MgCO_3$ equivalent to
28,180 of $CaCO_3$ per 2,000,000 of soil

No treatment



30 tons stable manure

$MgCO_3$ equivalent to
28,180 lbs. $CaCO_3$ per 2,000,000 of soil and
30 tons stable manure

28,180 lbs. $CaCO_3$ per 2,000,000 of soil and
48 tons stable manure

ment have shown variations from week to week as great as can be found between the analyses of the blank and magnesium-carbonate-treated rims of Table III. Furthermore, duplicate determinations upon a composite of the air-dried samples from 6 untreated rims gave a carbonate CO_2 occurrence of .074 per cent by boiling for 1 minute with 1-15 phosphoric acid and aspiration for 15 minutes, while duplicates upon 2 air-dried composites of 4 rims each, of the 8 magnesium-carbonate-treated rims of Table III, gave CO_2 occurrences of but .0672 and .0660 per cent, an average of .0666 per cent, upon being subjected to the same analytical procedure as the blank, 25-gram charges of soil being used in each case.

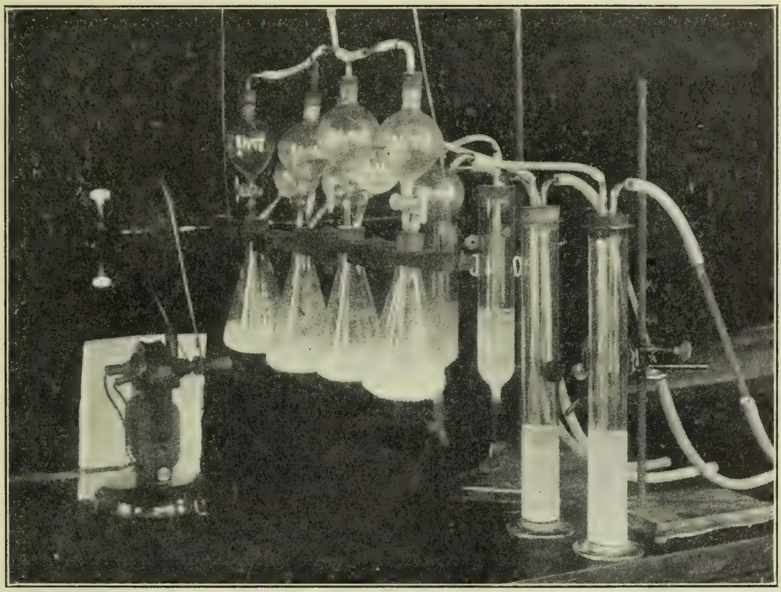
The carbonate determinations of Table III were also supplemented by further analyses. Twenty-five-gram charges of a composite sample of the 8 magnesium-carbonate-treated rims were subjected in duplicate to 4 hours' contact in cylinders with 500 cc of distilled water, saturated with CO_2, the soil being constantly agitated by a continuous flow of CO_2. These mixtures were immediately filtered at the end of the 4-hour period and titrated to neutrality against N-10 acid, methyl orange being used as an indicator. The duplicate determinations required 9 and 9 1-2 cc. The composite of the rims receiving precipitated calcium carbonate in amounts representing basicity equal to the magnesium carbonate, upon being treated at the same time in like manner to the magnesium carbonate composite, gave titrations of 48.6 and 48.7 cc. Table VIII shows that the precipitated carbonate of magnesium is more than 12 times as soluble as the precipitated carbonate of calcium; hence the absence of the applied precipitated magnesium carbonate is further substantiated. Table IX offers data tending to show the alkalinity found in the CO_2 extractions of magnesium carbonate treatments as being due to hydrolyzation and carbonation of the silicates of magnesium.

CONVERSIONS OF CALCIUM AND MAGNESIUM OXIDES TO CARBONATES WHEN APPLIED TO SOIL

The use by Hopkins[6] of finely divided magnesium carbonate in tests of the effect of magnesium upon plant growth is criticised by Gile[7], who attributes part of the injurious effects noted by Hopkins to causticity of the carbonate. Kearney and Cameron[8], however, recorded growth without apparent injury to the growing plants where the roots were immersed in a solution containing the suspended insoluble precipitated carbonate of magnesium, which was distinctly alkaline from the hydrate present. According to Sadler and Coblentz[9], "in moist air it (Mg O) readily absorbs moisture and CO_2, becoming converted into basic carbonate." Morley and Muir[10], Fresenius[11], and Loew[12] state that basic carbonate is formed from MgO in presence of water and CO_2. Loew further states, in objecting to the use of the precipitated carbonate in magnesium treatments, that ground dolomite

or magnesite should be used rather than "the artificially precipitated basic magnesium carbonates, which are very injurious, being easily absorbed, owing to their very fine pulverulent condition." In discussing the "Danger from using caustic magnesia and burned and hydrated magnesian lime," Wheeler[18] writes: "The preceding results show that caustic magnesia was toxic at first where it was used in large quantities, even on a soil evidently in slight need of magnesia, but that when sufficient opportunity had been afforded for it to become carbonated, it became useful."

PLATE 3



FOUR-UNIT FAN-MOTOR SHAKING APPARATUS USED FOR DETERMINING SOIL CARBONATES

The method is given in detail in Tenn. Sta. Bul. 100.

As supplementing the data bearing on the carbonation of burnt and hydrated lime reported in Table III, the carbonation of CaO in water solution, both with and without the presence of soil, was studied,

In order to test their relative rates of carbonation in water alone, 10-gram charges each of Kahlbaum's "C. P." freshly ignited oxides of calcium and magnesium were placed in separate graduated cylinders with 500 cc of distilled water and agitated by a current of CO_2 entering at the bottom of the cylinders, for a period of 4 hours. The solutions were then immediately filtered through Buchner funnels

with gentle suction, and their alkalinities determined in duplicate by titrations with standard acid, methyl orange being used as an indicator. *The average of the* 500-*cc duplicate extraction of MgO required* 1862.5 *cc of N*-10 *acid, while the CaO extractions required* 101 *cc of the same strength acid for neutralization, representing in equivalents, 18.63 and 1.01 grams, respectively, of calcium carbonate per litre* (See Table VIII). Oxide of magnesium being exceedingly insoluble in CO_2-free distilled water, the titrations clearly demonstrate the extensive reaction between MgO and carbonated water. While the comparison is based upon the amounts of the carbonates actually in solution and titrated as bicarbonates, it is very probably true that the entire charges, including the portions undissolved in the carbonated water, have been converted to the carbonate forms.

After thus demonstrating that magnesium oxide is readily carbonated in water and apparently more readily than lime, the procedure was repeated in the presence of definite amounts of a slightly alkaline

TABLE IV—*Comparison of carbonation of CaO and MgO in loam soil, CO_2 being supplied under laboratory conditions*

Treatments		Theoretical possible increase of CO_2 from treatment	Carbonate CO_2 occurrence by analyses after passage of CO_2	CO_2 liberated by acid from soil blank after passage of CO_2	Actu'l CO_2 increase due to carbonation of oxides	CO_2 increase of theory
CaO added Grams	MgO added Grams	Grams	Grams	Grams	Grams	Per cent
.3531	----------	.2774	.2338	.0067	.2271	81.87
2202	----------	.1730	.1713	.0067	.1646	95.14
.2698	----------	.2120	.1895	.0067	.1828	86.22
----------	.2514	.2767	.1618	.0067	.1551	56.05
----------	.2748	.3025	.1554	.0067	.1487	49.16
----------	.4210	.4634	.2244	.0067	.2177	46.98

soil. It is shown in Part II of this bulletin that magnesium carbonate reacts extensively with alkaline siliceous substances and decomposes when in contact therewith for a few weeks, and in order if possible to forestall the greater part of this anticipated reaction, the lime and magnesia were carbonated in contact with soil in the laboratory by the passage of CO_2 for 4-hour periods. Twenty-five-gram charges of soil which had received 2 tons of burnt lime per acre 9 months previously, and reacting alkaline to litmus, were placed in 300-c. c. Erlenmeyer flasks with 100 c. c of distilled water and treated with freshly ignited Kahlbaum's CaO and MgO, weighed from closed bottles. Currents of CO_2 were passed through the mixture of soil and water for 4 hours at room temperature and atmospheric pressure, duplicate blanks of the original soil being treated in the same manner. At the end of the period of contact with CO_2, the flasks were freed of CO_2 in solution by heating to boiling, cooled, and after standing overnight placed in a CO_2

train, the carbonate CO_2 being then liberated by 1-15 H_3PO_4, and determined gravimetrically.

The data of Table IV show a wide difference between the recoveries of CO_2 from the two carbonates. Although when tried in carbonated water alone, MgO showed an alkalinity about 18 times as great as that secured from CaO, as measured by the bicarbonates in solution, the recovery of CO_2 by acid from magnesium carbonate formed by carbonation of the MgO in the treated soil, is only about one-half that of the CO_2 liberated by acid from the carbonates resulting from the lime treatments. It is doubtless true that while all of the lime has been carbonated, a part of the calcium carbonate in solution has reacted with acid silicates and other acid salts of the soil (Tables XIV and XV), and that magnesium carbonate has acted in the same manner to a much greater extent. Then too, in the maximum charges of the triplicates upon both CaO and MgO, the carbonation actually effected is considerably more than would be required by the full amounts of CO_2 indicated by theory as needed for the complete carbonation of the smaller charges. It is quite apparent that the complete decomposition of magnesium carbonate upon long periods of contact with soil as shown in this bulletin has been accomplished in part very appreciably during the 4-hour period of contact with carbonated water and the standing overnight as carried out in the tests of Table IV.

Of the experiments available to the writer, only those of Frear[18] might be considered as parallel to those of Tables III and IV. Frear quotes Low and Davy as attributing toxicity of magnesian lime when applied to soils to the continued occurrence of the caustic form of magnesium. From his own experiments Frear concludes that magnesia carbonates more slowly than lime, and he attributes the harmful effect of magnesian lime to persistent causticity of magnesia.

In Dr. Frear's experiments "C. P." CaO and MgO in chemical equivalents were applied to soils, the reactions of which were not given, and contact permitted for 10 months, during 3 months of which time optimum moisture conditions were maintained. No check treatments of the carbonates of calcium and magnesium were used in the experiments cited. At the end of the 10-months period, analyses of the 9 soils treated with CaO gave a carbonate CO_2 content of .149 per cent, while an average of 8 of the same 9 treated with MgO (considering one analysis as typographical or other error) gave .051 per cent CO_2 as compared to .038 per cent CO_2 as the average of determinations on the 9 soils at the beginning of the experiment. In one instance, that of a muck soil, of the 9 lime treatments no increase of CO_2 was found, while in 4 cases of the 8 analyses quoted, there was no accumulation of CO_2 where magnesium oxide was added. These analyses led Dr. Frear to the conclusion that MgO is persistently caustic when applied to soils.

From the results given in this bulletin it would appear that the apparent lack of carbonation in the quoted results of Frear might then,

be the result of one or both of two possibilities rather than the persistent causticity of the magnesia; either the oxide has in the presence of CO_2 and water become carbonated and the carbonate in turn decomposed by the siliceous material and titanium oxide of the soil, or soluble silicic acid and acid silicates have acted directly upon the relatively insoluble MgO, with the formation of magnesium silicates and also titanates, as will be later shown in Part II of this bulletin. Reference to Table III will show that during a period of 8 weeks under field conditions, the 8 applications of 16,000 pounds of burnt lime per 2,000,000 of soil and equivalent amounts of hydrated lime had carbonated to practically the identical carbonate occurrences found in the treatments with the precipitated calcium carbonate. This table also shows that during the same period there was effected the complete dissipation of the CO_2 of the precipitated magnesium carbonate, in amounts equivalent to 28,180 pounds of $CaCO_3$ per 2,000,000 of soil. It is therefore probable that had equivalent amounts of oxide of magnesium been carbonated during the 8-weeks period, the decomposition of the carbonate by silicic acid reaction would have prevented the finding of magnesium carbonate upon analysis.

From the data of Tables III, IV and VIII, it would seem to be fully substantiated that the conclusions of Low, Davy, and Frear concerning the period of causticity resulting from applications of burnt magnesian lime are erroneous, as are also those of Wheeler concerning the accumulation of magnesium carbonate from excessive treatments of caustic magnesia. The period of *temporary* toxicity noted is due rather to extensive distribution of magnesia as a result of the fineness of division of the readily carbonated oxide, which is very soluble in carbonated water. The lime content of burnt magnesian lime treatments above soil "acidity" requirements would continue then, largely in the form of the more soluble carbonate, while the magnesia portion would exist in the relatively insoluble form of magnesium silicate.

COMPARATIVE ACTIVITIES OF CHEMICALLY EQUIVALENT AMOUNTS OF GROUND LIMESTONE AND GROUND DOLOMITE OF SIMILAR MECHANICAL COMPOSITION UNDER FIELD CONDITIONS

The use of chemically equivalent amounts of limestone and dolomite in the rim treatments affords opportunity for study of the activity of magnesium carbonate, when applied in the form of dolomitic limestone. The two materials were made to correspond in mechanical make-up to a local commercial product of ground limestone. The compositions, mechanical and chemical, of the two limestones are given in Table V.

The analyses to determine residual carbonates resulting from the

limestone and dolomite treatments were made 9 months after application of the materials. No leaching took place during the first 2 months of the period. A composite of 6 cores from each rim was ground to pass a 100-mesh sieve prior to analysis. Careful examination of the soils before grinding showed a few pieces of both limestone and dolomite still undisintegrated. The consistent and marked differences in residual carbonates between the 8 limestone rims and the 8 dolomite rims show an unmistakable activity of the magnesium carbonate content of the dolomite upon siliceous materials. Though all treatments were subjected to leaching during the last 7 months of the time intervening between treatment and analyses, the differences in residual carbonates could not be accounted for by leaching, because the limestone is 1.62 times as soluble as the dolomite in carbonated water, as is shown in Table VIII. Laboratory investigations reported in Tables XIV and XV served to eliminate consideration of the influence of organic matter in the phenomenon.

The decomposition of the dolomite would probably mean more finely divided calcium carbonate residue from this rock than from limestone, and the residual calcium carbonate of dolomite would probably approach in activity that of the finely divided precipitated carbonate.

TABLE V—*Mechanical and chemical analyses of the limestone and dolomite used in field treatments*

Through 10 mesh	100%
10 mesh to 2 mm	30.69%
2 mm. to 1 mm	18.73%
1 mm. to 1-2 mm.	18.55%
Less than 1-2 mm.	32.03%
	100.00%

	SiO_2	Fe_2O_3	CaO	MgO	CO_2 by analysis	CO_2 from determinations of CaO and MgO
Ground limestone	5.91	1.35	50.23	1.59	39.52	39.47
Ground dolomite	3.25	2.45	31.43	17.71	44.22	44.10

Tables III and VI also afford an interesting comparison of the effect of fineness and purity of calcium carbonate upon the extent of its reaction with siliceous materials. The precipitated carbonate at the end of an 8-weeks period with no leaching showed residual calcium carbonate amounting to 19,749 pounds per 2,000,000 of soil, while 7 months later, after exposure to fall and winter rains, the residual calcium carbonate from the applications of limestone amounted to 21,844 pounds per 2,000,000 of soil.

TABLE VI—*Residual carbonates from treatments of identical basicity, in forms of ground limestone and ground dolomite of similar mechanical composition upon a loam soil—period of contact, 9 months* [a]

Rim No.	M. f. soil Grams	Treatments equivalent to 28180 lbs. of $CaCO_3$ per 2,000,000 of soil	Carbonate CO_2 untreated soil m. f. basis Per cent	Carbonate CO_2 at end of 9 months m. f. basis Per cent	Variations between extremes and averages of duplicates Per cent + or	Increase of carbonate CO_2 over original soil during 9 months, m. f. basis Per cent	Increase of carbonate CO_2 over original soil during 9 months. Grams per rim	CO_2 increase over original soil calculated to $CaCO_3$, lbs. per A. 2,000,000 lbs.	Average residue of CO_2 in terms of $CaCO_3$, lbs. per A. 2,000,000 pounds of soil from limestone treatment
K 22	90720	Ground limestone & manure	.0394	.4883	.0064	.4489	407.24	20404	
L 22	"	" " " "	"	.5072	.0072	.4678	424.39	21264	
M 22	"	" " " "	"	.5285	.0072	.4891	443.71	22232	
N 22	"	" " " "	"	.4864	.0034	.4470	405.52	20318	
K 28	"	" " --------	.0318	.5616	.0012	.5298	480.63	24082	
L 28	"	" " --------	"	.5214	.0060	.4896	444.17	22545	21844
M 28	"	" " --------	"	.4599	.0016	.4281	388.37	19459	
N 28	"	" " --------	"	.5696	.0042	.5378	522.74	24445	
									Average residue of CO_2 in terms of $CaCO_3$, lbs. per A, 2,000,000 pounds of soil from dolomite treatment
K 23	"	Ground dolomite & manure	.0394	.2620	.0002	.2226	201.94	10118	
L 23	"	" " " "	"	.2694	.0052	.2300	208.66	10454	
M 23	"	" " " "	"	.3284	.0056	.2890	261.18	13136	
N 23	"	" " " "	"	.2744	.0028	.2350	213.19	10681	
K 29	"	" " --------	.0318	.3499	.0078	.3181	288.58	14459	
L 29	"	" " --------	"	.3521	.0112	.3203	290.58	14559	
M 29	"	" " --------	"	.2660	.0098	.2342	212.47	10645	11680
N 29	"	" " --------	"	.2383	.0030	.2065	187.34	9386	
Difference—representing dissipation of CO_2 from magnesium carbonate in dolomite, terms of $CaCO_3$									10164

a Solubilities of 100-mesh carbonates, represented by ratio of 1 to 1.62 for dolomite and limestone, respectively.

DECOMPOSITION OF MAGNESITE BY SOILS[a]

In the study of the activity of mineral carbonate of magnesium upon soils, 400 grams each of the three original "acid" soils of Table I were subjected to moist contact with 10 grams of analyzed 100-mesh magnesite in Erlenmeyer flasks at room temperatures. Thirty-gram charges of these moist mixtures were analyzed for residual carbonates at the end of 35 days, at the end of 65 days, and again after 138 days, correction being made in the calculations for the boiling blank on the original "acid" soils. It should be noted that none of the methods ordinarily used for carbonate CO_2 could be utilized in analyzing the magnesite. It was necesary to boil for 30 minutes to insure complete decomposition of the mineral. The amounts of magnesite decomposed by the soils were then compared with the Veitch-method requirements of magnesite. The extent of the decomposition above the amounts indicated by the Veitch method are shown in Table VII. The analyses indicate that magnesite undergoes the same decomposition as the magnesium carbonate of dolomite and precipitated carbonate, though less rapidly than the precipitated carbonate.

The activity of magnesite under field conditions is being further studied.

CAUSE OF TOXICITY IN THE SOILS OF TABLES I AND III (Plates 1 and 2)

The rim experiment cited in Table III upon one of the soils used in the basket experiments of Table I, showed that about twice as much carbonate of magnesium as was used in the baskets underwent complete decomposition within 8 weeks. The soils in the baskets were in contact with the excessive magnesium treatments, equivalent to about one-half of the rim treatments, for about 10 weeks prior to seeding of wheat. The conclusion is therefore drawn that magnesium carbonate had been dissipated through combination with siliceous materials prior to seeding of wheat and that the toxicity shown in Table II and Plate 1 is attributable to excessive amounts and great fineness of division of magnesium silicate, and is *not* due to presence of an excess of *carbonate of magnesium,* nor to an excess of caustic hydrate impurities of the precipitated carbonate, for this hydrate would have been converted to the bicarbonate, and this in turn decomposed by contact with siliceous materials. The tall oat grass shown in Plate 2 was sown in the magnesium-carbonate-treated rims, 10 months after treatments. The analyses of Table III show that this carbonate treatment, equivalent to 28,180 pounds of $CaCO_3$ per 2,000,000 of soil, was decomposed within 8 weeks, and the harmful effect upon the growth of grass cannot therefore be attributed to the continued presence of magnesium carbonate.

That the decomposition of magnesium carbonate is due not alone to acid silicates but to silica (SiO_2) and titanium oxide (TiO_2) in the

a Suggested to the writer, in personal correspondence, by Dr. H. J. Wheeler.

TABLE VII—*Decomposition of magnesite by contact with moist soils under laboratory conditions* [a]

Soil type	Total grams of air-dried soil	$MgCO_3$ indicated by Veitch method to neutralize soil acidity, m. f. basis		$MgCO_3$ added	Decomposition of $MgCO_3$—determined by analyses of residual carbonates, m. f. basis. CO_2 liberated from 30-gram charges by boiling 30 minutes with 1-15 H_3PO_4											
					After 30 days' contact				After 65 days' contact				After 138 days' contact			
						Excess of Veitch				Excess of Veitch				Excess of Veitch		
		Per cent	Grams	Grams	Grams	Grams	Per ct.	Lbs. per 2,000,000 of soil	Grams	Grams	Per ct.	Lbs. per 2,000,000 of soil	Grams	Grams	Per ct.	Lbs. per 2,000,000 of soil
Sandy clay loam	(A) 400	.0454	.1736	9.424	.5755	.4019	.105	2100	.6538	.4702	.123	2460	1.4288	1.2552	.328	6560
	(B) 400	.0454	.1736	9.424	.4979	.3243	.085	1700	.7070	.5334	.139	2780	1.3978	1.2244	.320	6400
	Av. 400	.0454	.1736	9.424	.5367	.3631	.095	1900	.6804	.5018	.131	2620	1.4133	1.2398	.324	6480
Silty loam	(A) 400	.0564	.2100	9.424	1.4082	1.1982	.322	6440	1.5313	1.3213	.355	7100	2.2449	2.0349	.547	10940
	(B) 400	.0564	.2100	9.424	1.5229	1.3129	.352	7040	1.5789	1.3693	.368	7360	2.3625	2.1525	.578	11560
	Av. 400	.0564	.2100	9.424	1.4656	1.2556	.337	6740	1.5551	1.3453	.362	7230	2.3037	2.0937	.563	11250
Loam	(A) 400	.1633	.5939	9.424	.9143	.3205	.088	1760	.9666	.3728	.102	2040	1.5802	.9863	.271	5420
	(B) 400	.1633	.5939	9.424	.9396	.3458	.095	1900	.9982	.4344	.119	2380	1.4822	.8884	.244	4880
	Av. 400	.1633	.5939	9.424	.9270	.3332	.092	1830	.9824	.4036	.111	2210	1.5312	.9374	.258	5150

a The flasks were shaken during the second and third contact periods.

presence of moisture is later shown in Part II of this bulletin (Tables XIII and XV) It is also shown later in this bulletin that though magnesium is present in the form of silicates as a solid in the soil mass, the silicates of magnesium in the presence of carbonated water will yield $MgCO_3$, and it is very probably true that in case of abundant amounts of CO_2 the hydrolyzation of the magnesium silicate may result in minute amounts of magnesium carbonate in the soil water, especially where magnesium silicate predominates over the occurrence of calcium silicate and where calcium carbonate is absent.

RELATIVE SOLUBILITIES IN CARBONATED WATER, OF THE CAUSTIC AND NEUTRAL MATERIALS USED THROUGHOUT THE EXPERIMENTS

As stated by Loew[14], and as shown in Table VIII, precipitated magnesium carbonate is many times more soluble than precipitated calcium carbonate in carbonated water, and had the magnesium carbonate persisted in the soil in this finely divided state in the rim treatments it would have been leached out more readily than calcium carbonate when treated with carbonated water. The figures for the solubility of calcium carbonate as given by different investigators vary considerably, but in all cases the amounts of calcium carbonate dissolved from forms other than native minerals, are far less than from similar forms of magnesium. Bischof[15] found 1.8 gram of $CaCO_3$ dissolved in a litre of carbonated water when using commercial burnt lime and 2.8 grams of calcium carbonate when using pure CaO; Treadwell and Reuter[15] found 1.3 grams of $CaCO_3$ per litre dissolved in carbonated water at normal pressure, and temperature of 13°C; while Anderson[16] has shown that the solubility of calcium carbonate is directly dependent upon the fineness of the material extracted with carbonated water. Engel and Ville[17] give 28.45 grams of $MgCO_3$ per litre as being dissolved in carbonated water at atmospheric pressure and 13°C.

As relating to the relative solubilities of the various forms of calcium and magnesium used in the experiments reported, the analyses of Table VIII are offered. Ten-gram charges in duplicate of each of the substances used were placed in graduated cylinders with 500 cc of distilled water and the masses of the materials agitated by a constant current of CO_2 entering through tubes leading to the bottoms of the cylinders. At the end of the four hours of contact at room temperature, 25°C, the mixtures were immediately filtered through Buchner funnels by gentle suction and the alkalinities of the filtrates determined by titration against N-10 acid, methyl orange being used as an indicator.

The comparisons between the finely divided burnt lime and oxide of magnesium, both being freshly burnt Kahlbaum's "C. P." products, and the precipitated carbonates, are extremely interesting as contrasted with the relative solubilities of the native carbonates ground to

TABLE VIII—*Comparisons of solubilities of calcium and magnesium compounds in carbonated water—period of contact 4 hours—10-gram charges*

Substance	C. P. CaO		C. P. MgO		Precip. $CaCO_3$		Precip. $MgCO_3$		Limestone 100-mesh		Dolomite 100-mesh		Magnesite 100-mesh	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
CC N-10 acid	100	102	1855	1870	117.4	117.2	1445	1432.5	88.6	90.8	55.8	55.0	28	27.5
≏ $CaCO_3$ grams per L	1.00	1.02	18.55	18.70	1.17	1.17	14.45	14.33	.89	.91	.56	.55	.28	.28
Length of crystals, mm	----		----		.0003		.0002		.005		.004		.003	

pass 100 mesh. The decided influence of the degree of fineness, determined from microscopic examination (camera-lucida attachment), is very striking. The figures upon the relative solubility of magnesite and limestone are closely in accord with those of Wheeler[18].

LACK OF EVIDENCE AS TO THE EXISTENCE OF MAGNESIUM CARBONATE IN SOILS

References on the part of many authorities to the existence of calcium and magnesium carbonates in soils are numerous, but the writer has been able to find but one definite and positive statement of the existence of magnesium carbonate where data are presented as proof of its occurrence. The existence of magnesium carbonate in soils, as analogous to calcium carbonate occurrences, has been assumed heretofore rather than proved. The citation referred to emanates from Argentina, and was published by Phipson in "The Chemical News"[19], 1902.

The work of Phipson was upon 8 soils, "taken with great care at the depth of one foot from the surface," and his analyses show as an average 1.09 per cent of CaO and 1.03 per cent of MgO.

From these analyses he concluded, "It is evident from these results that the lime is present as *dolomite*, which is not readily assimilated."

It is not without interest, however, to note that no reference to occurrence of CO_2 or its estimation is made, and the inference is that the determinations of CaO and MgO were from acid digestion of the soil, the conclusion as to the existence of carbonates resulting probably from the effervescence of the calcium carbonate. Loew[20] has reported an analysis of a soil near the Porto Rico Station, giving .60 per cent of CaO and 3.32 per cent of MgO, though the soil was *acid*. Acidity in such cases was considered by Loew[21] in later work as being due to acid silicates.

A four-day HCl 1.115 digestion in the cold of calcium and magnesium mineral silicates of Table IX, and of a composite from the 8 magnesium-carbonate-treated but carbonate-CO_2-free soils of Table III, gave large amounts of both calcium and magnesium dissolved from the silicate forms.

From 10-gram charges each of wollastonite and serpentine, 81 per cent of total CaO and 32 per cent of total MgO from the respective minerals were recovered by the cold acid digestion.

Since magnesium silicate is readily soluble in HCl, the data are not conclusive proof of the occurrence of magnesium carbonate, even in the subsoil under the conditions cited, and manifestly the conclusions of Phipson were not fully justified.

ABSENCE OF MAGNESIUM CARBONATE FROM VIRGIN SOILS

It seems eminently fair to assume from the observed extensive decomposition of the excessive amounts of precipitated magnesium car-

bonate and dolomite used in the basket and rim experiments that the natural processes being evolved for hundreds and thousands of years in surface soils would have effected the same decompositions of any residual carbonate of magnesium from the original soil-forming calcareous sandstone, limestone or dolomite.

Gaither[22], in a very comprehensive study of a large number of Ohio soils, concluded that there is a definite correlation between soil acidity, as shown by the litmus-paper test, and the absence of carbonates as shown by the Marr method. In examinations of many types of Eastern soils the writer has observed that it is a very rare exception to find a soil reacting alkaline to litmus, unless the soil has recently received lime treatment. It would seem then that many of our cultivated soils are without residues of native mineral carbonates of either calcium or magnesium.

The work of Gaither[22] and the results reported by MacIntire and Willis[5] indicate that in many cases of soil analyses the figures offered as representing carbonate CO_2 were not derived from carbonates, but from action of boiling acid upon soil organic matter.

The trace of magnesium as carbonate possibly existing in the soil solution upon long contacts of magnesium silicates with carbonated soil-water, and resulting from hydrolyzation and carbonation of silicate of magnesium, is not determinable upon the samples used in laboratory procedure.

Apparently an excess of silicates and, as will later be shown, of titanium oxide, is inhibitory to the long-continued presence of magnesium carbonate in soils, and we therefore feel compelled to conclude that none of the carbonate CO_2 found in dried virgin soils, as analyzed in the laboratory, can be accredited to combination with magnesium as magnesium carbonate.

POSSIBLE EXCEPTIONS TO THE CONVERSION OF MAGNESIUM CARBONATE TO SILICATES IN SOILS

In case of peaty soil underlaid by hardpan, which prevents efficient natural drainage, it may be that the usually large amounts of organic matter and the relatively small amounts of silica with which the carbonate has opportunity for contact may permit the retention of magnesium carbonate to an appreciable extent and that any toxic action upon plant growth observed subsequent to excessive applications of burnt magnesian lime or dolomite might be attributed to presence of magnesia dissolved as bicarbonate. In other words, absence or presence of but relatively meager amounts of silica and acid silicates would permit the existence of magnesium carbonate when excessively applied, though efficient drainage would mean its ready leaching, especially when formed from the finely divided burnt magnesian lime.

Because of the lack of opportunity for study of arid soils, the possibility of the existence of magnesium carbonate in such soils might

be assumed, though the observations of Hilgard[23] tend to show even more unfavorable conditions for the retention of magnesium carbonate in arid soils than in those of humid climates. Cameron and Bell[24] have shown that magnesium forms several soluble double salts with the alkali carbonates. This would probably mean a greater distribution and surface exposure of any applied magnesium carbonate to silica and acid silicates in arid soils than would be presented in field practice under humid conditions.

From numerous analyses, Hilgard found that the soluble silica in arid soils is about twice as great as that in humid soils, and that the same holds true of hydrous silicates, which in this bulletin will be shown to decompose magnesium carbonate readily by mere contact without CO_2 to effect solution of the carbonate. Tables XIV and XV show decidedly greater activity between acid silicates and magnesium carbonate, than between acid silicates and calcium carbonate, and it would therefore seem that the existence of magnesium carbonate in arid soils would be even less probable than in soils of humid climates. This, however, is a point to be further investigated.

It is also very probable that in subsoils near the native occurrences of substrata of limestone carrying some small amounts of magnesium carbonate, or formations of dolomitic character, that magnesium carbonate may occur in rock fragments which are still to undergo complete disintegration. Through personal communications, the writer has been informed by Mr. J. W. White, of the Pennsylvania Station, that he has secured samples of subsoil from one plat where the "mother rock" occurred within 2 feet of the surface, and that CaO determination would not account for all of the CO_2 resulting from analysis of the alkaline subsoil. On the other hand, from personal experience on the same plats, sampling to a depth of 7, 14 and 21 inches upon the 24 plats reported in Table XVI, the writer observed several large lumps of wet, swollen occurrences of stone as large as an orange, which on being easily perforated by the sampling auger at first glance appeared to be white clay, and which might easily have been included in the sampling, but for the personal observation and supervision of the collection of samples. The results of Table XVI show from the composite of 480 borings from subsoils 14 and 21 inches deep on the 24 plats, that even in the heaviest lime treatments the total CO_2, from analyses of these subsoils close to the native rock occurrence, is not sufficient in any of the 48 instances to account for the total lime as being in combination as carbonate, without considering the magnesium occurrence.

The results of Table XIII show that the texture of the soil influences the rapidity of the decomposition of the soil carbonates, and it is possible that in the coarse sandy soils of the coastal plains where hydrated silica occurrences are meager, the magnesium carbonate of treatments may remain for an appreciable length of time before being lost by

drainage or decomposition through reaction with the coarser siliceous materials. However, the sandy loam (Table I), from a peach orchard, completely dissipated the CO_2 of the carbonate of magnesium to an equivalence of 16,070 pounds of calcium carbonate per acre in excess of the Veitch-method indication, and upon being further treated in the laboratory the same magnesium-treated soil accomplishes still further decomposition, as shown in Table XIII. This sandy soil, however, contains considerable red clay.

THE SOLUBILITIES OF SILICATES OF CALCIUM AND MAGNESIUM IN CARBONATED WATER

Since it is evident that magnesium occurs in soils as magnesium silicate and not as magnesium carbonate, the question of the solubility of magnesium silicates in carbonated water assumes important proportions. In order to study the comparative solubilities of carbonate-free mineral silicates of calcium and magnesium with the carbonates of the two elements, the data of Table IX were secured. The various charges of the materials were introduced into graduated cylinders with 500 cc of distilled water. Carbon dioxide entering through glass tubes, extending to the bottoms of the cylinders, kept most of the material in suspension during the 4-hour period of the passage of the gas. The analyses show that silicates of calcium and magnesium undergo hydrolyzation and carbonation to an appreciable extent, the soluble silica in no case accounting for more than a small proportion of the amounts which would be in combination with the bases, even assuming that the silica occurring in the carbonated water is in combination with the bases as dissolved silicates, instead of occurring as soluble hydrated silica. It is also evident from the analyses of the calcium and magnesium silicates that where CO_2 is present in abundance, the presence of one silicate is neither inhibitory nor depressing to the action of carbonated water upon the other. The analyses further show that where the amounts of CO_2 introduced and the periods of contact are the same, variations in amounts of the silicate of same fineness constitute an important factor in determining the extent of reaction. This will evidently explain why in certain instances good stands of clover are maintained upon soil analyzing moderately well in total CaO, but acid to litmus and showing lime requirements upon dried samples in the laboratory. It is fair to assume from the analyses of the relatively coarse mineral silicates that with abundant supplies of calcium silicate under field conditions, the hydrolyzation and subsequent carbonation of the lime of the silicate will produce media of sufficient degree of alkalinity to maintain good growths of clover and other legumes. It is doubtless true that growing plants assimilate part of their store of magnesia as magnesium carbonate in the same manner.

This utilization of the lime of calcium silicate probably accounts

TABLE IX—*Comparisons of solubilities of finely ground mineral carbonates and silicates of calcium and magnesium in carbonated water—period of contact, 4 hours*

Substance	Wollastonite $CaSiO_3$ 10 grams	Limestone $CaCO_3$ 10 grams	Serpentine $MgSiO_3$ 10 grams	Magnesite $MgCO_3$ 10 grams	Wollastonite and serpentine each 10 grams	Precipitated chalk $CaCO_3$ 10 grams	Precipitated chalk and serpentine each 10 grams	Wollastonite 20 grams
N-10 acid to neutralize	54.2	90	21.6	28	69.35	117.3	121.2	92.2
Alkalinity = grams $CaCO_3$ per L.	.542	.90	.216	.28	.6935	1.173	1.212	.922
Grams of SiO_2 per L. in filtrate of carbonated water	.0566		.0162		.0840	.0020	.0254	

in part for the benefits derived by legumes from applications of Thomas slag, which has been shown to contain considerable of calcium silicate.

THE CONSERVATION OF MAGNESIA IN SOILS

In noting the excess of magnesia over lime as characteristic of tropical soils, Hilgard[25] attributes this to the "more ready solubility of lime in carbonated water," but he also says that dolomites weather more readily than limestones. However, Loew[21] cites an analysis of an "acid" soil near the Porto Rico Station, as giving .60 per cent of CaO and 3.32 per cent of MgO. Frear[26] states that dolomites as a rule weather more slowly than pure limestones, "though there are exceptions to the rule." It is probably true that compactness, degree of crystallization and purity of a limestone or dolomite have much to do with its weathering. As shown in the solubilities given in Table VIII, the limestone used in these experiments is appreciably more soluble in carbonated water than the dolomite. From the discovery of the decomposition of magnesium carbonate when in contact with alkaline siliceous substances, together with the solubilities of Table VIII, it seems probable that at first the weathering of limestone is much more rapid than that of dolomite, but as the weathering of dolomite proceeds with increasing occurrence of siliceous impurities in the rock residue, the decomposition of the dolomite may be stimulated by the additional activity resulting from the affinity of magnesia for silica (Tables XIII, XIV and XV,) and the decomposition of dolomite at the later period may be expedited beyond the extent of the limestone disintegration, as a result of the magnesia-silica reaction. Prof. C. A. Mooers, from twenty years' observation in the extensive Tennessee areas of soils derived from limestone and dolomite, has noted the greater depth of the dolomitic soils as compared with those of limestone derivations, and the frequency of the outcrops of limestone as contrasted with the less common dolomite outcrops. His investigations have further shown no excessive retention of magnesium in soils of dolomitic origin, their usual comparatively low productiveness being attributed by him to poverty of phosphoric acid. Hilgard[25] states that less magnesia than lime is found in soil leachings, and Hall[27] established from investigation upon drainage waters that but from 5 to 20 pounds of magnesia per acre per annum is lost by leaching, and that this is not appreciably increased by fertilizer treatments of magnesia.

The work of Lyon and Bizzell[28], Way[29], Clarke[30], and Zoller and Ulbricht, quoted by Frear[31], shows that lime is much more extensively leached than is magnesia. Tennessee soils derived from high-grade marble, the native rock analyzing 99 per cent $CaCO_3$, have less of residual CaO than of MgO. Hopkins[32], citing results of the Illinois State Water Survey, gives, from 90 analyses of well waters, 330

pounds of calcium and 130 pounds of magnesium as the leaching per acre per annum from estimated average rainfall. This is equivalent to a loss of 462 pounds per acre per annum of CaO and 217 pounds of MgO, a ratio of 2.21 to 1, while the determined solubilities of calcium silicate (wollastonite) and magnesium silicate (serpentine) in carbonated water were 2.10 to 1. The presence of native or applied calcium carbonate in soils would, of course, tend to increase the given ratio of lime to magnesia in drainage waters.

It is evident from the given solubilities of the various forms of magnesium carbonate, that were the carbonate existing in the soil, its leaching would be comparable with that of lime, and this fact, together with the decomposition of magnesium carbonate shown in Tables I, III, VI, VII, XIII, XIV and XV, forces upon us the conclusion that the occurrence of magnesium in the soil mass is in the form of silicate and not in the form of carbonate.

It appears, therefore, that the loss of magnesia from soils is the result either of the direct solubility of magnesium silicate or of the hydrolyzation and subsequent carbonation of the silicate when acted upon by carbonated soil water. The solubilities of the silicates of Table IX were, however, altogether negligible when in contact for 4 hours with distilled water at room temperature and at boiling temperature. Furthermore, the analyses of Table IX indicate that by far the largest proportion of soluble magnesia derived from action of carbonated water upon magnesium silicate (serpentine) is due to the presence of magnesium bicarbonate formed from the hydrolysis of the silicate. In the bicarbonate form, the magnesium would then be leached from the soils without subsequent conversion to the silicate, where drainage is sufficiently rapid.

THE DECOMPOSITION OF SOLUBLE SALTS OF MAGNESIUM BY SILICATES, WITH THE FORMATION OF INSOLUBLE MAGNESIUM SILICATES

Wagner[33] states that the successful use of Stassfurt salts containing magnesium chlorides and sulphates is dependent upon the presence of an excess of lime. Loew[13], quoting the observations of Schultz-Lupitz, concerning the corrective effects of lime applied to soils receiving kainit and carnalit, attributes the beneficial influences to correction of lime-magnesia ratio. The observations of Fleischer[34], who noted a greater benefit derived from the application of kainit in fall over spring treatment, indicated either a leaching of the harmful constituents of kainit and carnalit or their conversion and retention in the soil in some less soluble form. Loew[13] suggested the partial leaching of magnesium over winter, or the conversion of the soluble magnesium salts to the "less noxious carbonate," as accounting for the observation cited. Hall[27] found, however, but little leaching of magnesia, which seemed not to be appreciably affected by additions

of magnesia as sulphate. It was thought possible by the writer that magnesium sulphate and chloride might by mass action in the presence of an excess of carbonate of lime undergo a partial conversion to magnesium carbonate, with the replacement of the lime as the base with the acid radicle of the original magnesium salts, and that the resultant magnesium carbonate might then react with silicates, forming insoluble magnesium silicate. This reaction, however, was not produced in qualitative trials in the laboratory.

It was noted by Keitt[35] that kainit salts when mixed with basic slag are rendered insoluble in water. Hall[36] has shown that basic slag is not represented by the formula $Ca_4P_2O_9$, as was formerly held, but by the formula $(CaO)_5P_2O_5SiO_2$. This led the writer to try the reaction between calcium silicate and magnesium sulphate and magnesium

TABLE X—*Recovery of magnesia from magnesium sulphate contact-treatments with wollastonite and serpentine—Co_2-free distilled-water extraction*

Treatments	10 grams wollastonite .5000 gram MgO as MgSO4	20 grams wollastonite .5000 gram MgO as MgSO4	10 grams serpentine .5000 gram MgO as MgSO4	20 grams serpentine .5000 gram MgO as MgSO4
Grams MgO recovered in solution	.4891	.4732	.4913	.4804
Grams CaO replaced by MgO and found in solution	.0174	.0376	.0069	.0137

chloride. Ten and twenty-gram charges of calcium silicate (wollastonite) were in contact for 2 hours with .5 gram of freshly ignited "C. P." MgO converted to the neutral chloride and sulphate and dissolved in 150 cc of distilled water. The mixtures were then filtered, and it was found that appreciable amounts of soluble magnesia were rendered insoluble, and that lime was liberated instead. Pastes of the mixtures of magnesium sulphate and each of two mineral silicates, wollastonite and serpentine, in the same amounts were then permitted to stand for 14 days. The mixtures were then extracted with CO_2-free water and the extract analyzed, the magnesium determinations being made in quadruplicate.

The serpentine was used as a check upon any physical absorption, but the sample proved to contain some lime. The magnesia recovered and the lime liberated by the treatments are given in Table X. The influence of the amount and surface exposure of the silicates is plainly demonstrated by the analyses of Table X, which show direct propor-

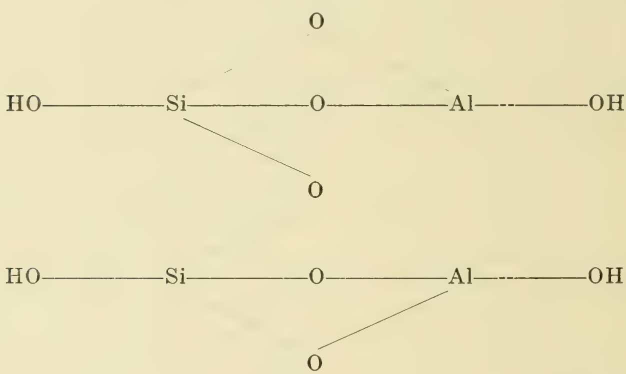
tion between the lime obtained in solution and the amount of silicates used in making the pastes, the amount of magnesia being a constant. Water blanks upon the two minerals show negligible extractions.

It would thus seem that the reason for the disappearance over winter of the temporary sterility attributed to applications of kainit and carnalit is accounted for by the affinity of MgO for SiO_2, and direct action between the soluble magnesium salts and calcium and possibly other silicates, resulting in the formation of the insoluble magnesium silicates.

PART II
LABORATORY INVESTIGATIONS

STUDIES OF THE MATERIALS EFFECTING DECOMPOSITION OF SOIL CARBONATES

The existence in the soil of acids, and acid-salts, including acid silicates, such as clays, is usually conceded by soil chemists and is mentioned in the standard works upon soils. The activity of clays in effecting the decomposition of soluble carbonates was noted by Morse and Curry[37]. They found that the bases were removed from solutions with the formation of bicarbonates or free CO_2 and concluded that the amounts of bases removed from solutions are dependent upon the concentration of the carbonate solutions. Loew[38] advanced the designation "argillic" acid and accounted for the dual acid and alkaline activities of clay by the formula—



Having in mind the well-known affinity of magnesia as magnesium chloride for silica in the dry, when dehydrating silica at temperatures above 120°C, the writer determined to study the effects of magnesium carbonate over lengthy periods and at room temperatures upon hydrated and dehydrated quartz of different degrees of fineness, as well as hydrated and dehydrated clays and other silicates occurring in soils. Calcium carbonate was also tried, the precipitated analyzed salts of both calcium and magnesium being used, except where the use of dolomite was specified.

PRELIMINARY STUDIES AS TO THE APPROXIMATE MOISTURE CONTENT GIVING MAXIMUM ACTIVITY BETWEEN SILICEOUS MATERIALS AND CARBONATES

The plan followed in determining activities between carbonates and the various soils and soil constituents was to bring the carbonates into contact with the various substances in CO_2-free atmosphere in air-tight Erlenmeyer flasks, from which subsequent to treatments the atmosphere was exhausted at intervals, and any liberated CO_2 drawn off by suction and determined gravimetrically in soda-lime U tubes (see frontispiece). The first test was made to determine the moisture condition giving the greatest activity, a loam soil being used for contact with precipitated magnesium carbonate. In order to eliminate the biological influences without introducing the factor of heat, treatments of neutral benzoate of soda were made to obtain sterile conditions in the preliminary experiments to determine the amount of moisture favoring the maximum activity. The benzoate of soda for each charge of soil was made by the conversion of .4 gram of benzoic acid to sodium benzoate.

Three moisture conditions, air-dry, estimated "optimum" of 15 per cent, and 200 cc in addition to 15 per cent air-dry basis, were maintained upon 200-gram charges of a loam soil, which had been in contact for a year with a large excess of calcium carbonate, (Table I). The benzoate of soda was introduced in solution into each of the nine 200-gram soil charges. Three charges were restored to air-dry condition, three to estimated "optimum" and three were given the excess of 200 cc above "optimum" moisture. The 9 charges, representing the three moisture conditions in triplicate, were placed in 500-cc Erlenmeyer flasks, which were stopped with two-hole rubber stoppers, through which were inserted glass tubes, the in-takes extending to the bottom of the flasks. The intakes and outgoes were connected with Geisler stopcocks, and cotton filters were placed in the tubing to prevent any dust being aspirated off from the dry treatments. The magnesium carbonate was thoroughly mixed throughout the charges and the atmosphere of the flasks freed of CO_2. The flasks were then closed and permitted to stand for one week, after which time and at regular intervals thereafter the CO_2 was drawn off and determined by the apparatus shown in the frontispiece. The excess moisture flasks were periodically agitated during aspiration to facilitate expulsion of CO_2 from solution. The averages of triplicate determinations covering a period of contact of 152 days are given in Table XI. The CO_2 in each of the magnesium carbonate treatments amounted to .7396 grams. It will be seen, however, that the CO_2 liberated from the "optimum" moisture flasks was considerably in excess of that amount, *seeming* at first to indicate an absorption of the base from

TABLE XI—*CO_2 evolved from contact of 2 grams $MgCO_3$ with 200 grams of the alkaline loam soil of Table I, in the presence of sodium benzoate*

Treatment	Grams of CO_2 evolved after												
	7 Days	14 Days	21 Days	28 Days	35 Days	42 Days	56 Days	63 Days	77 Days	95 Days	109 Days	116 Days	152 Days
Air-dried	.0051	.0060	.0078	.0091	.0120	.0141	.0162	.0184	.0198	.0254	.0283	.0373	.0522
"Optimum"	.1793	.4100	.5507	.7272	.8916	1.0536	1.1851	1.2606	1.3285	1.3690	1.4141	1.4712	1.5046
200 cc excess H_2O	.0247	.0709	.0984	.1145	.1454	.1819	.2268	.2665	.3156	.3671	.4262	.4726	------

sodium benzoate and liberation of the acid radicle, which in turn apparently acted upon the large amount of residual calcium carbonate in the soil, resulting from treatment prior to that of magnesium carbonate and benzoate of soda.

This observation seemed interesting in its apparent relation to selective absorption, and the reason for the excess of CO_2 above the amount of that applied as $MgCO_3$ was further studied (Table XII).

CO_2 EVOLVED BY CONTACT OF ACID AND ALKALINE SOILS WHEN TREATED WITH NEUTRAL SODIUM BENZOATE

In Table XII are given the activities of sodium benzoate treatments on the original acid loam soil and on the two carbonate-treated soils of Table I, of which the acid and magnesium-carbonate-treated soils were shown by analysis to be free of carbonate CO_2, while the calcium-carbonate-treated soil contained a considerable excess of carbonate. Two hundred grams of moist soil were treated in each case as described for the analyses of Table XI. It is evident from the analyses of Table XII that the CO_2 evolved in excess of the amount supplied by the magnesium carbonate, in the carbonate and benzoate treatments with "opium" moisture content shown in Table XI, cannot be due to the action of the benzoic acid radicle upon the excess of calcium carbonate, since greater amounts of CO_2 are evolved by decomposition of the sodium benzoate in both original acid soil and the alkaline magnesium-treated carbonate-free soil than from the soil

TABLE XII—*Evolution of CO_2 from contact of sodium benzoate with an "acid" loam before and after calcium and magnesium carbonate treatments of Table* I

Soil	Reaction to litmus	Previous treatment	Grams CO_2 evolved after				
			14 days	28 days	56 days	92 days	147 days
Loam	Acid	None	.1337	.2727	.4002	.4662	.5001
"	Alkaline	$MgCO_3$	.1087	.2197	.3082	.3904	.5014
"	Alkaline	$CaCO_3$	.0927	.1049	.1948	.2544	.3407

containing an excess of calcium carbonate. In fact the excess of carbonate appears to have a somewhat depressing effect upon the CO_2 evolution. The conversion to CO_2 of the total carbon in .4 gram of the original benzoic acid as the sodium benzoate of the treatment, would give a theoretical carbon occurrence of .2752 gram, while .1366 gram of carbon has been evolved in the average CO_2 evolutions of the two carbonate-free soils of Table XII. Assuming the benzoate of soda to be the source of the carbon of the CO_2 evolved, rather than the soil, it is evident that oxygen has been secured from a source other than carbonates. Oxidation by the atmospheric oxygen of the flasks was suggested by the fact that suction was characteristic of all the treatments involving benzoate of soda, though it was not notice-

able in the case of the minerals used in the Erlenmeyer flasks experiments.

MAGNESIUM CARBONATE IN MOIST CONTACT AT ROOM TEMPERATURES WITH VARIOUS SILICEOUS SUBSTANCES MADE STERILE BY HEAT

Tables XI and XII demonstrated that "optimum" water content gave favorable conditions for activity between soil and magnesium carbonate, and that the presence of sodium benzoate involves complications. The use of sodium benzoate was then discontinued. Further contacts of the earthy carbonates and siliceous materials were made in Erlenmeyer flasks with "optimum" moisture content, sterilization being effected by heat in an autoclave, after the introduction and mixing of the carbonates with the charges of siliceous materials. The materials used to decompose earthy carbonates in this series were coarse and very fine white quartz sand, SiO_2 (silt, E. & A.), crude kaolin, clay and alkaline soil of the three types of Table I. The treatments were, (a) 2.5 grams of $MgCO_3$, (b) 2.5 grams of $MgCO_3$ and 2 grams of $CaCO_3$, and (c) 3 grams of dolomite, the analysis of which is given in Table V. *The three soils used had already received treatments of magnesium carbonate equivalent to* 16,070 *pounds per acre of* $CaCO_3$ *in excess of the Veitch-method requirement and had been subjected to this contact for a period of one year without leaching, being however, free of carbonates at the beginning of the second treatment of Table* XIII, *as shown by the analyses of Table* I.

DISCUSSION OF RESULTS OF TABLE XIII

The data of Table XIII eliminate consideration of biological influences and indicate clearly that the reaction responsible for the decomposition of magnesium carbonate is due largely to silica and silicates. The reaction is shown to be dependent upon the fineness of both the carbonate and the siliceous materials. The presence of calcium carbonate does not appear to be inhibitory to the reaction. While in most cases there seems to be less of CO_2 evolved from the mixtures of precipitated carbonates of calcium and magnesium, this is probably accounted for by the fact that the carbonate of lime contains some hydrated oxide of calcium, which would combine with a part of the CO_2 evolved. It will be shown later in this bulletin that to a lesser degree calcium carbonate appears also to act upon silica.

Had the reactions responsible for the data given resulted from soils alone, either the possible activity of carbonates upon soil organic matter or the influence of CO_2 upon the solubility of the precipitated $MgCO_3$ might be advanced as a factor in the evolution of CO_2, but the contacts were effected in many other cases than those cited in Table XIII, with absolute freedom from organic matter and CO_2 gas. If the reaction involved in the decomposition of the carbonates be considered

TABLE XIII—CO_2 *evolved from earthy carbonates in contact with siliceous materials at room temperatures, under sterile conditions*

Siliceous materials 200 grams	Reaction	Treatments	Grams CO_2 evolved after c										Equivalent in $CaCO_3$	
			7 days	14 days	21 days	28 days	42 days	63 days	79 days	111 days	150 days	205 days	Grams	Lbs. per 2,000,000 of soil
Coarse sand	Alkaline	$MgCO_3$ e	.0009	.0044	.0065	.0118	.0153	.0192	.0260	.0358	.0393	.0397	.0902	902
" "	"	" and $CaCO_3$ e	.0032	.0083	.0120	.0163	.0217	.0288	.0356	.0430	.0490	.0539	.1225	1225
" "	"	Dolomite e	.0033	.0055	.0063	.0124	.0213	.0275	.0341	.0377	.0454	.0502	.1141	1141
Very fine sand	Alkaline	$MgCO_3$	.0082	.0126	.0216	.0343	.0546	.0619	.0664	.0827	.0923	.1000	.2272	2272
" " "	"	" and $CaCO_3$	.0033	.0079	.0129	.0265	.0393	.0568	.0615	.0669	.0780	.0912	.2072	2072
" " "	"	Dolomite	.0024	.0117	.0132	.0163	.0267	.0278	.0311	.0332	.0377	.0419	.0952	952
Silt	Alkaline	$MgCO_3$	.0413	.0558	.0825	.1102	.1491	.1682	.1828	.1851	.2050	.2268	.5155	5155
"	"	" and $CaCO_3$	.0044	.0205	------	.0399	.0534	.0666	.0868	.0937	------	.1037	.2357	d 2357
"	"	Dolomite	.0024	.0055	.0208	.0345	.0502	.0581	.0638	.0677	.0371	.0985	.2238	2238
Clay	Alkaline	$MgCO_3$	.1651	.2242	.2799	.3349	.4236	.4468	.4503	.4712	.4846	.4971	1.1297	11297
"	"	" and $CaCO_3$	.1202	.1759	.2250	.2464	.3268	.3608	.3706	.3834	.3896	.4061	.9229	9229
"	"	Dolomite	.1816	.2115	.2377	.2594	.2836	.3063	.3094	.3199	.3308	.3526	.8013	8013
Kaolin	Alkaline	$MgCO_3$	.0338	.0789	------	.1029	.1193	.1441	------	.1536	.1652	b.1807	.4107	4107
"	"	" and $CaCO_3$	.0251	.0655	------	.0803	.0958	.1062	------	.1265	.1337	b.1518	.3450	3450
"	"	Dolomite	.0262	.0475	------	.0662	.1040	.1175	------	.1264	.1323	b.1563	.3552	3552
Loam a	Alkaline	$MgCO_3$	.0563	.1092	.1820	.2382	.3153	.3657	.3969	.4152	.4353	.4569	1.0384	10384
"	"	" and $CaCO_3$	.0825	.1384	.2055	.2686	.3364	.3579	.3727	.4045	.4191	.4370	.9932	9932
"	"	Dolomite	.0267	.0479	.0790	.1109	.1304	.1527	.1587	lost	.1840	.2139	.4861	4861
Sandy loam a	Alkaline	$MgCO_3$	.0282	.0472	.0579	.0846	.1278	.1458	.1575	.1702	.1978	.2336	.5309	5309
" "	"	" and $CaCO_3$	.0241	.0436	.0638	.0903	.1012	.1198	.1308	.1425	.1601	.1857	.4224	4224
" "	"	Dolomite	.0165	.0493	.0548	.0677	.0874	.1057	.1262	.1273	.1414	.1734	.3941	3941
Silty loam a	Alkaline	$MgCO_3$	.0379	.0907	.1325	.1815	.2554	.3101	.3255	.3346	.3406	.3766	.8559	8559
" "	"	" and $CaCO_3$	.0390	.0709	.0990	.1573	.1974	.2291	5.289	.2807	.2916	.3346	.7604	7604
" "	"	Dolomite	.0169	.0410	.0660	.0952	.1426	.1776	.1891	lost	.2137	.2436	.5536	5536

a One year previously treated with excess of $MgCO_3$ = 16070 lbs per acre $CaCO_3$ above Veitch requirement.
b Total period 14 days less than other 7 sets due to later beginning.
c Occasionally shaken at intervals other than 79-111 days.
d Two weeks less contact than other two silt treatment due to loss of original.
e $MgCO_3$, 2,5 grams; $CaCO_3$, 2 grams; dolomite, 3 grams.

as a function of solubility, it would appear that the solubility of the siliceous materials is as much the controlling factor as the solubility of the earthy carbonates, if not more so.

ACTIVITY OF SILICON DIOXIDE

In his treatise upon the synthetical preparations of crystalline alkali silicates, Morey[39] writes:

"It must be emphasized, however, that conclusions in regard to the relative strength of silicic acid based on the apparent degree of hydrolysis of such solutions are not necessarily valid; indeed, there is ground for the belief that silicic acid is considerably stronger than has generally been supposed."

Frear[40] quotes Hilgard as finding high lime content accompanying soluble silica and alumina in prairie soils of Alabama, Mississippi and Texas. According to Frear[40], quoting Storer, old mortars are often found to contain notable quantities of hydrous silicates, so that "caustic lime must be able to attack even the strongly resistant grains of sand." The experiments of Stockhardt are also quoted to the effect that caustic lime attacks powdered quartz as well as gelatinous silica. Wagner[41] cites experiments of Petzholdt, von Schrotter and Walters as proving that the hardening of mortar is in part due to the formation of calcium silicate, and the superiority of the mortar in structures built by the Romans is attributed to the mixing of sand with newly hydrated lime as contrasted to present-day methods. Sadler and Coblentz[42], and Spiller[43] assert that the setting of mortar is independent of the formation of calcium silicates and is due entirely to the carbonation of the hydrated lime. Though the influence of the formation of calcium silicate upon the setting of the mortar appears to be a disputed point, there is apparently no contradiction as to the actual formation of a compound resulting from the contact of caustic lime with quartz. It would appear from the data of this article that the observations noted as to the activity of the lime upon silica may be in part attributed to the action of carbonated lime upon siliceous materials. At least, CO_2 is evolved from contact of pure SiO_2 and "C. P." $CaCO_3$ under moist conditions at room temperatures. The evolutions of CO_2 from contact of silica with $MgCO_3$, noted in Table XIII, demonstrate that there is a decided affinity of MgO for SiO_2 and that the silicic acid radicle extensively replaces that of carbonic acid. As might be expected, the 100-mesh dolomite, relatively coarse as compared to the precipitated salts, was less active in most cases, but its CO_2 evoltuions were quite appreciable.

FURTHER STUDIES UPON THE DECOMPOSITION OF CARBONATES AS EFFECTED BY VARIOUS SOIL MINERAL CONSTITUENTS

After observing the decomposition of applied carbonates, with the elimination of both biological activities and influence of the

presence of organic matter, as shown in Table XIII, various soil mineral materials were studied in relation to their activities upon precipitated magnesium and calcium carbonates. Two hundred grams of each of the finely ground mineral materials were used for the contact treatments designated in Tables XIV and XV without sterilization in 500-cc Erlenmeyer flasks.

Weigner[44], in his studies of absorption by silicates, which he considers as a chemical reaction when regarded as an exchange of bases, concluded that dehydration lessened absorption, and that fineness of the silicate has but little influence upon absorption. In order to include observations of the comparative activities of the original substances, with action subsequent to dehydration, the various materials were ignited in platinum in a muffled furnace, for 16 hours. Gooch, Rickert and Kerzirian[45] found that all water is driven from hydrated silica in 30 minutes' heating of small charges over an ordinary Bunsen flame, but because of the bulk of the charges used the ignitions in the experiments reported were continued for an overnight period of 16 hours. Water equivalent to that of hydration was restored, and the moisture made equivalent to that of the unignited materials just before the carbonate treatments were applied.

Because of the usual occurrence in soils of appreciable amounts of titanium oxide and its close relationship to SiO_2, a pure form of titanium ore, 98 per cent TiO_2, was included among the substances used. The writer endeavored to secure acid-titanates, but was unable to secure the ore sought. According to Hopkins[46], of the 2 per cent of the solid crust of the earth other than silica and silicates, a large part is due to the occurrence of titanium, and, quoting the Geological Survey, he gives for an average 5300 pounds of titanium for 2,000,000 of soil in four loess soils from Illinois, Mississippi, Iowa and Missouri. The writer has found large quantities of titanium in the Hagerstown silty clay loam of limestone origin at the Pennsylvania Station. Dunnington[47] asserts that the element occurs universally. Hall[48] states that examinations of most sands show occurrences of rutile. Wait[49] found the element as a constituent of a large number of plant ashes and natural occurrences of coal. He has also shown the writer data from a number of analyses of clays, the TiO_2 percentages of which vary from 2.8 per cent to 4 per cent.

Solutions of sodium silicate were also tried as to their action in contact with the earthy carbonates. Hendrick's[50] analyses of commercial water glass indicate that the substance is principally an acid silicate, $NaHSiO_3$. With the 1 to 1 dilution as used, there was no evolution of CO_2 secured at room temperatures, but the lack of any apparent physical effect of the solution upon calcium carbonate, as contrasted with the slimy formation resulting from the magnesium-carbonate treatment, was very noticeable.

TABLE XIV—*Decomposition of magnesium and calcium carbonates by long periods of contact with earthy materials under "optimum" moisture conditions at room temperatures*

Siliceous materials	Grams used	Reaction	Treatment of substance before addition of carbonates	Carb'ate treatm't $MgCO_3$ 21-2 grms $CaCO_3$, 2 grams	Grams CO_2 evolved after 14 days	28 days	56 days	a 78 days	a 133 days	CO_2 loss in terms of $CaCO_3$, grams	CO_2 loss in terms of $CaCO_3$, lbs. per A. 2,000,000 of soil
Red clay	200	Alk.	None	$MgCO_3$	.2242	.3349	.4352	.4545	.4605	1.0466	10466
" "	"	"	"	$CaCO_3$	.0247	.0466	.0567	.0606	.0677	.1538	1538
Loam	200	Alk.	1-yr. cont'ct xs of $CaCO_3$--carb'n-free by oxygen	$MgCO_3$	.0214	.0462	.0727	.1053	.1262	.2868	2868
"	"	"	" " " " " " " " "	$CaCO_3$	.0127	.0233	.0277	.0302	.0351	.0797	797
Loam	200	Alk.	1 yr. after large excess $MgCO_3$, ignited 16 hrs.	$MgCO_3$	.0229	.0342	.0590	.0799	.0994	.2259	2259
"	"	"	" " " " " " " "	$CaCO_3$	.0210	.0318	.0409	.0566	.0680	.1545	1545
Kaolin	200	Alk.	Ignited 16 hours	$MgCO_3$	.0097	.0320	.0473	.0561	.0613	.1393	1393
"	"	"	" " "	$CaCO_3$	.0170	.0221	.0379	.0457	.0574	.1304	1304
Kaolin	200	Alk.	None	$MgCO_3$	.0789	.1029	.1319	.1344	.1485	.3375	3375
"	"	"	"	$CaCO_3$	.0052	.0071	.0219	.0483	.0560	.1272	1272
Kaolonite	200	Alk.	None	$MgCO_3$	.0041	.0161	.0242	.0312	.0408	.0928	928
"	"	"	Ignited 16 hours	"	.0100	.0159	.0237	.0310	.0428	.0972	972
Kaolonite	200	Alk.	Ignited 16 hours with 20 grams $MgCO_3$	$MgCO_3$	.0063	.0090	.0090	.0099	.0152	.0345	345
"	"	"	" " " " 20 " $CaCO_3$	"	.0005	.0046	.0058	.0065	.0074	.0168	168
Bauxite	200	Alk.	None	$MgCO_3$	.0403	.0574	.1081	.1496	.1838	.4177	4177
"	"	"	Ignited 16 hours	"	.0052	.0057	.0126	.0195	.0324	.0736	736
Hornblend	200	Alk.	None	$MgCO_3$	.0063	.0099	.0154	.0185	.0237	.0538	538
"	"	"	"	$CaCO_3$	0	.0044	.0065	.0092	.0131	.0297	297
Hornblend	200	Alk.	Ignited for 16 hours	$MgCO_3$	.0016	.0032	.0032	.0060	.0085	.0193	193
"	"	"	" " " "	$CaCO_3$	.0025	.0036	.0046	.0050	.0078	.0177	177

a Flasks not agitated during the period of 78 to 133 days.

Table XV—*Decomposition of magnesium and calcium carbonates by long periods of contact with earthy materials under "optimum" moisture conditions at room temperatures*

Siliceous materials	Grams used	Reaction	Treatment of substance before addition of carbonates	Carb'ate treatm't $MgCO_3$, 2 1-2 grms $CaCO_3$, 2 grams	Grams CO_2 evolved after: 14 days	28 days	56 days	a 78 days	a 133 days	CO_2 loss in terms of $CaCO_3$ Grams	CO_2 loss in terms of $CaCO_3$ lbs. per a 2,000,000 of soil
Rutile	200	Alk.	None	$MgCO_3$	.0608	.0941	.1191	.1469	.1803	.4097	2731
"	"	"	"	$CaCO_3$	.0060	.0133	.0203	.0368	.0479	.1089	726
Opal	200	Alk.	None	$MgCO_3$	.0102	.0190	.0272	.0370	.0425	.0965	965
"	"	"	"	$CaCO_3$	.0096	.0176	.0320	.0411	.0523	.1188	1188
Opal	200	Alk.	Ignited 16 hours	$MgCO_3$	.0045	.0093	.0171	.0216	.0271	.0616	616
"	"	"	" 16 "	$CaCO_3$	.0053	.0112	.0153	.0206	.0264	.0600	600
Silt	200	Alk.	None	$MgCO_3$	.0558	.1102	.1587	.1834	.2013	.4575	4575
"	"	"	"	$CaCO_3$	.0728	.0937	.1174	.1428	.1789	.4066	4066
Red clay	200	Alk.	None	$MgCO_3$	.2242	.3349	.4352	.4545	.4801	1.0910	10910
" "	"	"	Ignited 16 hours	"	.0121	.0183	.0261	.0336	.0468	.1036	1036
Soapstone	200	Alk.	None	$MgCO_3$	.0029	.0068	.0140	.0181	.0211	.0479	479
"	"	"	"	$CaCO_3$	.0084	.0126	.0169	.0229	.0308	.0700	700
Kaolinite	200	Alk.	None	$MgCO_3$	.0041	.0161	.0242	.0312	.0408	.0927	927
"	"	"	"	$CaCO_3$	.0097	------	.0148	.0179	.0231	.0525	525
Serpentine	200	Alk.	None	$MgCO_3$	.0238	.0322	.0614	.0722	.0930	.2113	2113
"	"	"	"	$CaCO_3$	.0018	.0065	.0076	.0157	.0246	.0559	559
Serpentine	200	Alk.	Ignited 16 hours	$MgCO_3$	.0033	.0041	.0094	.0139	.0369	.0838	838
"	"	"	" 16 "	$CaCO_3$	.0037	.0037	.0037	.0037	.0037	.0084	84
Alum. silicate	200	Acid	None	$MgCO_3$	.0426	------	.2053	.2253	.2266	.5150	5150
" "	"	"	Ignited 16 hours	"	.0454	------	.0945	.1305	.1744	.3963	3963
Rutile	200	Alk.	Ignited 8 hours	$MgCO_3$	.0020	.0079	------	------	b.0186	b.0287	b287
"	"	"	" 8 "	$CaCO_3$	.0040	.0078	------	------	b.0125	b.0422	b422

a Flasks agitated during the period of 78 to 133 days.
b Total period of contact, 91 days.

DISCUSSION OF THE ACTIVITIES BETWEEN THE CARBONATES AND SILICEOUS MATERIALS

Inspection of Tables XIV and XV demonstrates that the condition of the siliceous materials with reference to their hydration has an appreciable influence upon the activities shown, especially in the case of clay. It is also noted, however, that after ignition the silica seemed able to recover sufficient water to effect its chemical combination with the bases of the carbonates. Although in every case of ignition the evolution of CO_2 from carbonate treatment is reduced, the action of magnesium carbonate after ignition is still quite appreciable, and greater throughout than the activity of calcium carbonate, as measured by the evolution of CO_2. The acid silicates, including even the magnesium silicate (serpentine), show a decidedly greater decomposing effect upon magnesium carbonate than upon calcium carbonate. There seems to be no great difference between the measures of activity of calcium and magnesium carbonates in combining with silt and hydrated SiO_2 (opal), but the greater affinity of magnesia for TiO_2 is plainly indicated. The two loam soils of Table XIV are those of Table I and for a year they had been in contact with excessive calcium and magnesium treatments. However, at the time of the treatment given in Table XIV there were present no residual carbonates from the original magnesium carbonate treatment of Table I. The 16-hour ignitions of the two soils were accomplished in a muffle furnace as in the cases previously cited, but the gentle ignitions with oxygen, which was used in an attempt to eliminate organic matter at a temperature not effecting dehydration, were accomplished by gentle relay heatings in platinum dishes in the open, a current of oxygen being supplied to the soil mass.

It is a matter of no great surprise that the calcium and magnesium carbonates in large quantities with large surface exposure should act as do the more soluble carbonates, as shown by Morse and Curry[51], when brought into contact with acid or hydrated silicates, resulting in liberation of CO_2; but the decomposition of the two carbonates, relatively insoluble in the absence of CO_2, resulting from their being brought in exceedingly dilute solutions to the relatively insoluble SiO_2 or the reverse, is an interesting phenomenon. Aberson[52] concluded, from his studies of the functions of absorption, that the phenomenon is a function of the surface of colloidal substances. Weigner[53] in his conclusions as to the lack of effect of fineness of silicates in influencing their activities, considers the phenomenon as a chemical reaction, and he noted the quick attaining of an equilibrium between the silica "gels" and ammonium salts. The limits of the activities of the excessive treatments of the earthy carbonates and siliceous materials studied have not been as yet, either quickly or entirely attained in our investigations, and the extent of the decompositions is the subject of further studies planned. It was observed that agitations be-

Plate 4

Erlenmeyer Flasks Containing the Mixtures of Precipitated Earthy Carbonates and Siliceous Materials

tween the periods of withdrawal of the CO_2 from the atmosphere of the Erlenmeyer flasks, caused considerable increase in the gas evolved over that obtained by permitting the mixtures to remain in the flasks without disturbance. The observations made by the writer have led to the conclusion that the reaction shown to transpire as the result of contact between magnesium carbonate and pure SiO_2 and TiO_2 is, considered as absorption, a chemical phenomenon rather than one of physical nature.

Inspection of Table XV shows that the dehydration of pure SiO_2 and TiO_2 has a diminishing effect upon the decomposition of the earthy carbonates. The degree of fineness of materials, and the extent of hydration, which the pure dehydrated silica seems capable of recovering in some measure upon being moistened, are apparently the factors controlling the extent of the phenomenon of decomposition of the carbonates, especially of magnesium carbonate.

Since the data of Tables XIV and XV were tabulated it has been found that some of the dehydrated materials, especially serpentine, are increasing their activities, as measured by the CO_2 evolved. The TiO_2 of Table XV has subsequently been treated for 10 days with an excess of caustic soda, then freed of the alkali and treated as was the original oxide with precipitated magnesium carbonate. At the end of 104 days 140 milligrams of CO_2 were drawn off from 300 grams of rutile. The finding concerning TiO_2 and SiO_2 suggests parallel activities of the oxides of Zirconium, Germanium, and other metals of the same chemical group.

CONVERSION OF $CaCO_3$ TO SILICATES IN SOILS IN FIELD PRACTICE

Laboratory investigations reported in this bulletin have shown that the magnesia of magnesium carbonate has a decidedly greater affinity for SiO_2 and silicates, and for TiO_2, than has the lime of calcium carbonate; but the activity of calcium carbonate, though more slow, is continued and extensive in the ultimate, especially in soils rich in clay. The cumulative conversions of calcium carbonate to forms other than carbonate in practice, are shown in Table XVI, the analyses being from peroxide fusions by the writer upon soils of the lime-treated plats of the General Fertilizer Experiments of the Pennsylvania Station, and are offered through courtesy of Prof. F. D. Gardner, head of the Department of Agronomy of the Pennsylvania Station. These analyses, as yet unpublished, are to appear in the delayed 1911-1912 report of the Pennsylvania Station. The 2-ton-per-acre applications of burnt lime were made every 4 years to the corn, while the ground limestone treatments were made every 2 years upon the corn and wheat, the rotation being corn, oats, wheat and grass. The analyses were upon composite samples of 40 borings, 10 from each of the 4 plats receiving each specified treatment. Of

TABLE XVI—*Analyses of 24 plats, of the Pennsylvania Station, showing pounds per acre of lime occurring as carbonates, as compared with total and other forms, after 32 years' treatment*

Composites of plats on all 4 tiers

Plat No.	16			22			23			24			33			34		
Treatment	Manure 6 tons			Burnt lime 2 tons Manure 6 tons			Burnt lime 2 tons			None			Gypsum 320 lbs.			Ground limestone 4 tons		
	Total CaO	CaO as $CaCO_3$	CaO in other forms	Total CaO	CaO as $CaCO_3$	CaO in other forms	Total CaO	CaO as $CaCO_3$	CaO in other forms	Total CaO	CaO as $CaCO_3$	CaO in other forms	Total CaO	CaO as $CaCO_3$	CaO in other forms	Total CaO	CaO as $CaCO_3$	CaO in other forms
O—7 inches	7576	1641	5935	20045	9267	10778	21192	10912	10280	7883	1902	5981	7985	1459	6526	19573	9741	9832
7—14 "	7924	1693	6231	11548	5105	6443	2188	2188	7701	7043	1067	5976	7228	1641	5587	13165	4505	8660
14—21 "	8906	3802	5104	9912	2265	7647	2474	2474	6207	7043	1902	5141	7760	1380	6380	10319	4167	6152
O—21 inches	24406	7136	17270	41505	16637	24868	15574	15574	24188	21969	4871	17098	22973	4480	18493	43057	18413	24644
Variation from check	+ 2437	+ 2265	+ 172	+ 19536	+ 11766	+ 7770	+ 17793	+ 10703	+ 7090	------	------	------	+ 1004	391	— 1395	— 21088	— 13542	— 7546
Increase of CaO, percentage of application	------	------	------	61.1	36.8	24.3	55.6	39.7	15.9	------	------	------	51.0	0	51.0	62.8	40.3	22.5

the total amount of lime added, an average of the three basic-form treatments gives an accumulation of 20.9 per cent of the aggregate of treatments in forms other than carbonates. Of the conserved lime from treatments, nearly 35 per cent is found in siliceous and other combinations other than calcium carbonate. As the CO_2 determinations were made by boiling 1 minute with 1-15 H_3PO_4 without application of a blank for activity of the acid upon soil organic matter, the CO_2 results are undoubtedly higher than actual occurrence, and the absolute amounts of the other combinations of CaO are, therefore, greater than they are shown to be by the analyses. Some small amounts of the lime applied are probably combined in organic forms and much

TABLE XVII—*Total K_2O per acre in limed plats of the Pennsylvania Station after* 32 *years of treatment—Same samples as in Table* XVI (*J. L. Smith method*)

Plat No.__	16	22	23	24	33	34
Treatment	Manure 6 tons	Manure a 6 tons Burnt lime 2 tons	Burnt lime 2 tons a	None	Gypsum 320 lbs.	Ground limestone 2 tons b
O-7 inches	75544	66574	66523	68253	72440	69154
7-14 "	72645	70076	68714	69673	67312	65653
14-21 "	65827	67721	66523	76136	66410	57705
O-21 "	214016	204371	201760	213062	206162	192412

a Every 4 years.
b Every 2 years.

has probably replaced potash in silicates, as shown in Table XVII. These data were secured, at the request of the writer, by Messrs. E. S. Erb and W. Thomas, under the direction of Dr. Wm. Frear.

INFLUENCE OF TIME IN THE DECOMPOSITION OF MAGNESIUM CARBONATE WHEN APPLIED TO SOILS

The indications from our work are that the retention in soils of magnesium in the form of carbonates in determinable amounts is of but brief duration, even with applications far in excess of requirements of practice. The first analyses of the rim treatments of the precipitated magnesium carbonate in excessive amounts were made 8 weeks after the applications, and at that time the entire applications, equivalent to about 16 tons per acre of fairly pure limestone, had disappeared without interference from leaching. The magnesia of magnesian lime would be expected to carbonate (Table VIII) and act in a similar manner to the precipitated carbonate.

The dolomite decomposition has been shown to be extensively, if not entirely, effected within 9 months, the first sampling period after treatment equivalent to 28,180 pounds of $CaCO_3$ per 2,000,000 of soil, while the activity of magnesite under field conditions is being made the subject of further study. It is to be expected that the mag-

nesium carbonate of the more dense dolomite and magnesite will require more time for decomposition than the finely divided precipitated magnesium carbonate, but their decompositions represent the identical reaction and will eventually occur. The time required in the accomplishment of the last named reactions would vary, of course, with the type of soil, the form and amount of treatment, and the mechanical handling of the soil. According to the laboratory analyses embodied in Table XIII, considering the CO_2 evolved from the dolomite treatment as coming from its magnesium carbonate content, in the case of the alkaline clay, nearly 2 tons of dolomite per acre 2,000,000 pounds, would have been decomposed in practice during the first week of contact.

The determinations of the limits of the magnesia-silica reaction and periods required for decomposition of various forms of magnesium carbonate, as influenced by soil type and composition, climatic and other factors, are yet to be determined.

RELATION OF THE FINDING CONCERNING THE DECOMPOSITION OF MAGNESIUM CARBONATE UPON OTHER INVESTIGATIONS

Since the announcement by Loew[53] of his hypothesis and the work of Loew and May[54] concerning the functions of calcium and magnesium in plant growth, much pot work upon the subject has been reported. Some investigators, notably those of the Imperial University and the Central Agricultural Experiment Station of Japan, have reported results which were considered by them as confirming Loew's hypothesis, while various other investigators in Europe and America have concluded that Loew's reasoning is fallacious and that his hypothesis has not been substantiated. Varying results have been reported from the use of soil and sand as media, while the treatments of finely divided precipitated magnesium carbonate have given results not in accord with those secured by the use of magnesite. In most of the investigations reported either magnesite, precipitated carbonate or sulphate has been used as a source of the applied magnesia.

Without entering into a discussion of the merits of Loew's hypothesis, it would appear from the data submitted in this bulletin that in many cases reasonings have been advanced upon the erroneous assumption of the continued presence of magnesium carbonate subsequent to its application to soils. The data presented indicate most emphatically that the presence of the usual soil components is altogether inhibitory to the continued existence of magnesium carbonate as a mineral solid in soils, when the magnesium carbonate is applied as the precipitated carbonate or as dolomite or magnesite.

It is apparent that when treatments of precipitated carbonate were made upon natural soils, the existence of magnesium carbonate was of but brief duration, while in the sand cultures the carbonate

remained much longer, because of the lesser activity of magnesia upon the relatively coarse grains of SiO_2 and because of the absence of the acid silicates and titanium oxide occurring in clays. The same would probably apply to the sulphates and chlorides of magnesium. Under all conditions the magnesium carbonate of dolomite and magnesite would probably remain longer than the carbonate of the precipitated salt before decomposition and conversion to silicate. However, the solubilities of magnesite and magnesium silicate (serpentine) in carbonated water, are not greatly different, and there would be no great disparity between the amount of magnesia available to plant growth from the native silicate and magnesite of equal fineness.

The solubility and fineness of a magnesium treatment have been shown to be very important factors in determining its toxic effect. Daikuhara[55] showed that when lime is present in soils as calcium carbonate, the necessary amount of magnesia when applied as magnesium sulphate is so small that the best ratio becomes 60 to 1. Although magnesia is decidedly less soluble as the silicate than as the original precipitated form, the fineness of the silicate resulting from the reaction of silica and the precipitated carbonate would still give appreciable availability of the magnesia through hydrolysis, as compared to the magnesia derived by solution of the relatively coarse mineral magnesite. The fineness of the original source of the applied magnesia would, though its influence upon the dissemination and surface exposure of the magnesium silicate resulting from treatment, affect the occurrence of magnesia available to plant growth. In other words, with a definite amount of CO_2 in soil moisture, the magnesia in solution would vary with the surface exposure of the silicate. Magnesium silicate derived from equal amounts of the magnesia as precipitated carbonate or magnesian lime would be more extensively disseminated than silicates derived from magnesite or dolomite as the source of the oxide. In soil cultures, then, the amount of magnesia coming in solution to the plant would depend upon the source of magnesia of the silicate and the amount of CO_2 present; the reaction of carbonate decomposition being shown to be reversible, resulting in the hydrolyzation and carbonation of the magnesium silicate.

The studies upon the relative solubilities of mineral calcium and magnesium silicates and the natural carbonates of the two elements demonstrated that calcium silicate is about 2½ times as soluble in carbonated water as magnesium silicate, and that ground limestone is about 1⅔ times as soluble as native calcium silicate (Tables VIII and IX). It would therefore seem that where equal amounts of lime and magnesia are found in soils, all of the lime in the mineral form of calcium carbonate and magnesia as native or converted magnesium silicate, the amount of calcium carbonate in *solution* and available to plant growth would be more than 4 times as great as magnesium carbonate (in terms of calcium carbonate, representing

equal alkalinity), whereas, were both occurrences of calcium and magnesium in the form of silicates, the ratio of the two compounds in solution would be represented in terms of calcium carbonate by 2½ to 1. The relations as to solubility are based upon assumptions that the compounds are of same fineness.

It is evidently established by the investigations here reported that the relative influences upon plant growth of the occurrences of lime and magnesia in soils, in their relation to each other, and jointly to the other essential elements, are entirely dependent upon the amount and form (silicates or carbonates) of the calcium occurrences and the amount of CO_2 in the soil to effect carbonation and solution of the hydrolyzed magnesium, which in its solid, inorganic chemical form in the soil mass is shown to be almost entirely a constant; i. e., magnesium silicate.

THE MAGNESIA-SILICA REACTION AS APPLIED TO PRACTICE

Given practical application, the research shows that when lime and magnesia are applied to soils in amounts in excess of those required to correct soil "acidity," magnesia is entirely converted to silicates, while lime is found partly as carbonate and partly as silicate, both of which are much more readily leached than is magnesium silicate. Where excessive treatments of lime and magnesia are given, as burnt magnesia-lime or as dolomite, or when these materials are repeatedly applied to the same soil, there will be at some future time an accumulation of the more insoluble magnesium silicates, while the lime will have been extensively lost by leaching. This accumulation of magnesia above the amount of lime conserved would mean eventually a condition which would be toxic to plant growth, and which would require remedial lime treatment in the future, though the soil might still be alkaline to litmus. Type of soil and climatic conditions would influence the factor of time required for the attainment of this probable toxicity. It is not apparent, however, that any deleterious conditions would be expected to materialize for many years as a result of the use of dolomite or burnt magnesian lime in the amounts ordinarily used in practice, nor do we find justification for giving preference to ground limestone over dolomitic limestone of equal basicity in conservative farm practice of the present.

SUMMARY AND CONCLUSIONS
PART I

The CO_2 of "C. P." precipitated magnesium carbonate, chemically equivalent to check treatments of 8 tons per acre of calcium carbonate in excess of the Veitch-method lime requirement, was dissipated by contact with fallow soils of three distinct types during a period of one year, without the interference of leaching.

The 8-ton-per-acre-equivalent applications of magnesium carbonate were decidedly toxic to wheat.

Repetition of the experiment under field conditions showed that in all of eight instances magnesium carbonate equivalent to 28,180 pounds of $CaCO_3$ per acre 2,000,000 of soil had been entirely decomposed at the end of 8 weeks without leaching, chemically equivalent amounts of burnt lime, hydrated lime and precipitated calcium carbonate being used as check treatments.

The precipitated magnesium carbonate exhibited no physical indications of the heavy treatment at the end of 8 weeks, while applications of chemically equivalent amounts of precipitated calcium carbonate were plainly discernible to the naked eye.

The 8-ton applications of burnt lime per 2,000,000 pounds of soil were shown to be completely carbonated within 8 weeks.

Magnesia was shown to be more readily converted to carbonate in soils than is lime.

The temporary toxicity usually attributed to magnesian lime and precipitated magnesium carbonate treatment was shown to be due, *not* to the persistence of causticity, which remains but briefly.

The harmful effects upon wheat and tall oat grass shown in Plates 1 and 2 were found to be due to finely divided and extensively diffused magnesium silicate, and *not to the applied magnesium carbonate,* which had been decomposed prior to the seedings.

Both the oxide and the precipitated carbonate of magnesium were many times more soluble in carbonated water than the corresponding forms of calcium; but in the case of the native mineral carbonates, limestone was 1.62 times as soluble as the dolomite and more than 3 times as soluble as the magnesite.

Decomposition of precipitated magnesium carbonate was found to be appreciably effected overnight by an alkaline loam soil under laboratory conditions. It was shown that magnesia is decidedly more active than lime upon the siliceous material of soils when the two bases are dissolved in carbonated water.

An average of eight treatments each of ground limestone and ground dolomite, of similar mechanical composition, and chemically equivalent in each case to 28,180 pounds of $CaCO_3$ per 2,000,000 of soil, gave 21,844 and 11,680 pounds, respectively, of residual calcium carbonate at the end of 9 months, though the limestone was 1.62 times as soluble as the dolomite in carbonated water.

The influence of purity and fineness of the applied materials upon the occurrence of residual carbonate is shown by the average residue of 19,170 pounds of $CaCO_3$ per 2,000,000 of soil, 8 weeks after application of chemically equivalent amounts of oxide, hydrate and precipitated carbonate of calcium without leaching, as compared to 21,844 pounds of residual calcium carbonate, 9 months after treatment of ground limestone of equal basicity.

That the decomposition of magnesium carbonate is not entirely a function of solubility of the carbonate is indicated by the comparison between the residual carbonates of limestone and dolomite treatments.

Amounts of magnesite, considerably in excess of the Veitch-method lime-requirement indication were decomposed by moist contact with each of the 3 soils of Table I.

If the magnesia-silica reaction be considered as a function of solubility, the solubility of the silica seems as important as that of magnesium carbonate in effecting of the reaction.

The solubilities of the mineral calcium and magnesium silicates used were negligible in CO_2-free water at normal and boiling temperatures.

Hydrolysis of calcium and magnesium silicates is accomplished to an appreciable extent in carbonated water, calcium silicate yielding much greater alkalinity than magnesium silicate.

An abundance of calcium silicate seems to function in producing alkalinity as well in carbonated water as one-half of an equal amount of calcium carbonate of the same fineness and of comparable purity.

Where an excess of CO_2 is maintained as the constant, the hydrolyzation of a mechanical mixture of the two silicates seems to be effected as though hydrolyses were accomplished separately.

With excess of CO_2 as the constant, the alkalinity produced by the hydrolyzation of either of the two silicates varies with the mass of the silicate.

No conclusive proof of the existence of magnesium carbonate in soils could be found in previously published data.

The occurrence of magnesia in the carbonate-free magnesium-carbonate-treated soils was shown by extraction in the cold with HCl, sp. gr. 1.115. The carbonate-free wollastonite and serpentine used gave large amounts of CaO and MgO dissolved by the same treatment.

The observations have led to the conclusion that soil activities

extending over thousands of years have completely decomposed any residual carbonate of magnesium in virgin soils, and that applications in practice are soon decomposed, even under decidedly calcareous conditions without drainage; that is, except for the minute quantities in soil moisture, resulting from hydrolyzation of silicates, or immediately after carbonate treatment, before decomposition has been effected, magnesium is not to be found in the carbonate form in surface soils.

The experiments indicate that with the greater occurrence of clays and hydrated silicates in the upper subsoil, magnesium carbonate would be even more quickly decomposed there than in the surface soil.

Possible exceptions to absence of magnesium carbonate, due to its decomposition by siliceous materials, are noted in unstudied arid soils, which, however, would appear to react as do humid soils, though more extensively; in peaty soils, very deficient in silica; in the coarse sand of the coastal plains, especially soon after magnesia treatment; and where subsoil rock has not completely disintegrated.

The loss of magnesia from soils is shown to be attributable to the hydrolyzation of magnesium silicate and its leaching in the bicarbonate form.

The greater loss of lime from calcareous soils is shown to be due to the decidedly greater solubility of calcium carbonate over that of magnesium silicate, while in "acid" soils the lime lost is also greater than the magnesia, because of the more ready hydrolysis and carbonation of calcium silicate over that of magnesium silicate.

The application of soluble, neutral sulphate and chloride in solution, and in form of paste, to insoluble calcium silicate, resulted in the formation of insoluble magnesium silicate, with the liberation of lime to the sulphuric acid radicle.

With the soluble magnesium salt as a constant the formation of the insoluble magnesium silicate was proportional to the mass of calcium silicate used.

The above reaction probably explains the temporary sterility following field treatment of Stassfurt salts without lime.

PART II

In original studies as to the causes for the entire dissipation of the CO_2 of magnesium carbonate when in contact with soils, benzoate of soda was used to maintain sterile conditions in the treated soils, but it was found that this salt could not be used because of complications.

When in moist contact with an alkaline loam soil, previously receiving heavy treatments of precipitated magnesium carbonate, neutral sodium benzoate was decomposed with oxidation and copious evolutions of CO_2. The same soil in its original acid condition acted in the same manner.

Sand, both coarse and fine, clay, kaolin, silt and three soils pre-

viously excessively treated with $MgCO_3$ (Table I) effected the decomposition of precipitated magnesium carbonate by moist contact at room temperatures both with and without the presence of precipitated calcium carbonate, each substance being alkaline and sterile by heat.

Dolomite in contact with the above materials under moist and sterile conditions at room temperature also evolved CO_2.

Pure alkaline SiO_2, hydrated and dehydrated, evolved CO_2 from moist contact with precipitated carbonates of calcium and magnesium and dolomite at room temperatures.

The magnesia of precipitated magnesium carbonate showed decidedly greater affinity for TiO_2 than did the lime of precipitated calcium carbonate; the decomposition of magnesium carbonate being extentively effected by moist contact at room temperatures with alkaline TiO_2.

The constant decomposition of carbonate of magnesium observed in the preliminary pot and field work seems due to the great affinity of magnesia for SiO_3, hydrated silicates, and TiO_2.

Hydrated silicates gave greater decomposition before dehydration than afterward, though appreciable decompositions were effected even after dehydration.

Clay, opal, loam soil, kaolin, kaolinite, bauxite, hornblend, rutile, silt, soapstone, serpentine, and C. P. aluminum silicate gave appreciable decomposition of the precipitated magnesium carbonate before and after ignition for 16-hour periods, the magnesium carbonate being almost invariably more active than precipitated calcium carbonate under both hydrated and dehydrated conditions.

Magnesium silicate (serpentine) was appreciably active upon magnesium carbonate, indicating that the possible extent of the activity between soil and magnesium carbonate is far beyond the limits to which the reaction has been subjected in our field experiments.

Soils strongly alkaline from excess of calcium carbonate effect the decomposition of magnesium carbonate.

Citations from unpublished analytical results secured from the Pennsylvania Station plats show that the action of burnt and carbonated lime upon siliceous materials, with formation of silicates of calcium, is extensive and cumulative in field practice.

The finding concerning magnesium carbonate decomposition, when applied to different pot culture work, has considerable bearing thereon, explaining what otherwise would be decided variations and discrepancies in previous work involving magnesia treatment.

The results indicate that ground dolomite might be used even in excessive amounts without any immediate toxic effect upon plant growth. However, the greater loss of lime by leaching of carbonate and hydrolyzed silicates, would produce at some future time conditions which would necessitate extensive liming to overcome magnesia poisoning.

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Agricultural Experiment Station

OF THE

University of Tennessee

BULLETIN NO. 108 JUNE, 1914

SUMMER-PRUNING THE PEACH

BY

C. A. KEFFER

GREENSBORO, 5 YEARS OLD

One of main limbs, pruned immediately after harvesting of crop of 1913

KNOXVILLE, TENNESSEE

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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

SUMMER-PRUNING THE PEACH

By C. A. Keffer

It is the usual custom to prune peach trees while they are dormant, in late winter or early spring. The peach fruits on shoots made the previous season. When the pruning is done in winter, or before growth begins in the spring, the new growth has the entire season for its development. In the peach, as in almost all trees, the terminal growth is stronger than the laterals, and when summer pruning is not practiced the more rapid growing upper shoots shade the lower, slower growing ones, in most cases causing their death. The result

Fig. 1, Greensboro, 5 Years Old
Pruned immediately after crop was harvested (early June)
(See photograph of main limbs of this tree on title page)

is that year by year the fruiting wood gets farther and farther from the ground; and in the course of five or six years, even when the trees are regularly pruned, it is necessary to use high stepladders to harvest the crop. And every few years dehorning becomes advisable, if the tree is to be kept within reasonable limits.

Moreover, when the fruiting wood is permitted to form prin-

cipally toward the outer parts of the main limbs the bark of these near the base of the tree is open to sun-scald during the winter, thus shortening the life of the tree. The difficulty of spraying, as well as of harvesting, is greatly increased when the trees are high. For all which reasons it is desirable to keep the crowns of peach trees as close to the ground as possible.

In order to get a full crop from a low-crowned tree, however, approximately as much fruit-bearing wood is necessary as in trees of the usual shape. The purpose of summer pruning is to enable the

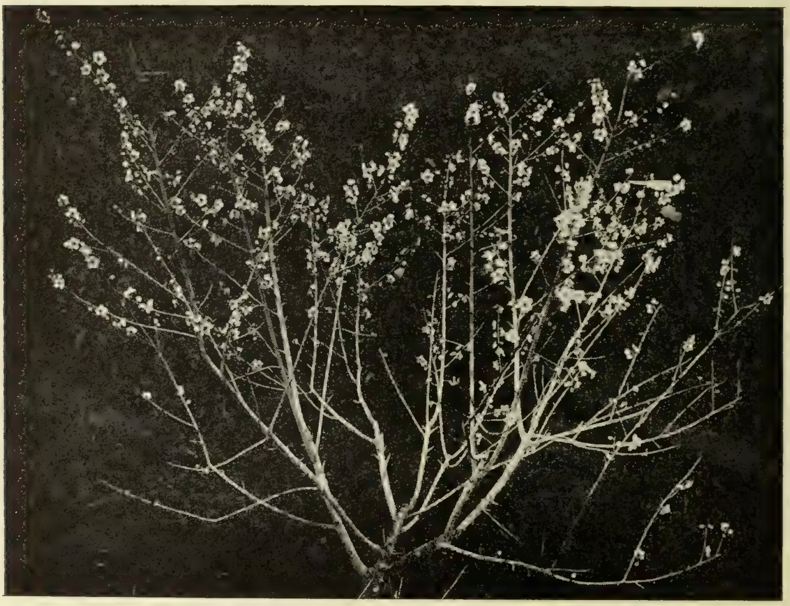

FIG. 2, GREENSBORO, 5 YEARS OLD
Not summer-pruned

tree to develop fruiting wood on the lower part of the main, or skeleton, branches, which are usually bare.

Seventy trees, including early and late varieties, were set in orchard in 1908, the distance being 18x20 feet. An investigation of the peach-tree borer required additional young trees, and in the spring of 1909, one-year-old trees were interplanted, so that the orchard stood 9x10 feet. As the trees came into bearing it was deemed desirable to ascertain how long they could be kept profitable at this close distance. Of course, heavy pruning was resorted to, and last year the usual winter pruning was supplemented by summer pruning.

Previous work of a similar nature had proven that in seasons

of average moisture the Greensboro and all earlier varieties set a crop of fruit buds after their harvest. In 1913 the Greensboro was ripe the first week in June. Red Bird was ripe May 23d. These two varieties were pruned the second week in June. The trees were divided into four groups, with an unpruned checkrow, and in each group the wood of the previous year's growth, whether it had produced peaches or not, was pruned back to varying lengths, from one to eight inches. By far the best results attended the close pruning. Where the spur was very short the new growth in many cases sprung from its base, and at most it was close to the main limb that supported it. But in the long spurs in most instances the new growth was near the extremity of the spur, thus defeating measurably the purpose of the pruning, and there were many spurs that did not send out new shoots.

FIG. 3, GREENSBORO, 5 YEARS OLD
Pruned in August

In all cases of early pruning the new wood was well set with fruit buds during the season, as is shown in Fig. 1, a picture of a Greensboro tree photographed when in full bloom, April, 1914. It is difficult by photography to show the fruit on the tree because leaves and fruit are so near the same color, and the picture is necessarily greatly reduced. As the peach blooms in advance of leafage, the blossoms show exactly the location of the fruiting wood and trees in full bloom are therefore used in illustrating this article.

Comparing Fig. 1 with Fig. 2, a tree that was not summer-pruned, it is seen that the result of summer pruning is to bring the

fruit of the next season nearer to the main limbs, and also that in the unpruned tree the lower part of the crown has very many less blossoms than the tree that is pruned by the middle of June. The picture on the title page is a detailed view of the lower part of one of the main limbs of the tree shown in Fig. 1. In the lower lefthand corner the trunk of the tree and its separation into three main limbs is shown. It will be observed that this limb (and the others equally) is clothed with blossom-covered shoots from its base outward, and fruit set on every one of these shoots, so that fully a fourth of the entire crop of the tree is produced within four feet of the ground. All the

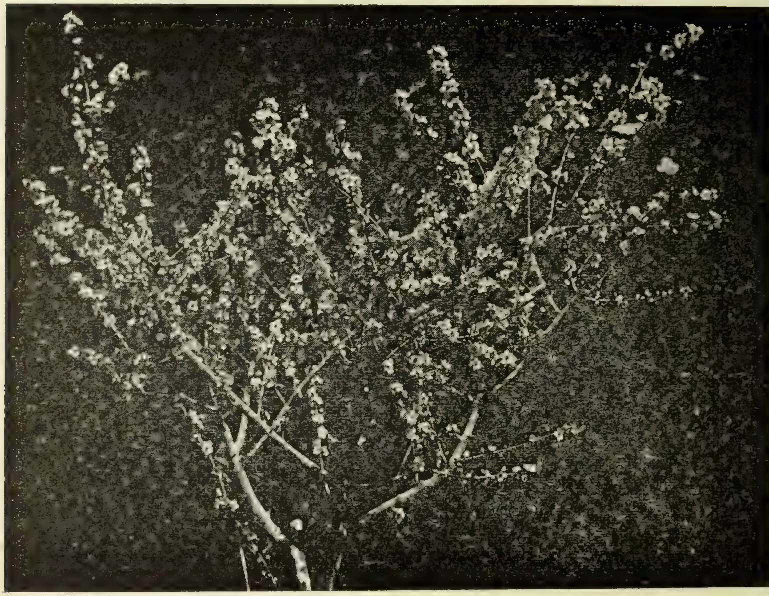

Fig. 4, Greensboro, 5 Years Old
Pruned in July

fruit on the tree can be picked from the ground by a man of average height.

Early summer pruning permits the formation of fruit buds for the next year's crop during the remainder of the growing season. But late pruning is harmful to the succeeding crop. The tree shown in Fig. 3 is a Greensboro tree that was pruned in August. Very few fruit buds formed on the new growth, which was very short. A Greensboro tree, pruned in July (Fig. 4) set a good stand of fruit buds in the upper part of the crown, but the lower part is relatively bare. Red Bird trees pruned in early June were quite as full of bloom in the lower branches as was the Greensboro tree shown in Fig. 1.

The later varieties respond in practically the same manner to early and late summer pruning. Fig. 5 is a Belle (of Georgia) tree pruned in early June, and Fig. 6 is a Belle that was not summer-pruned.

The late-pruned Belles were no better than the late-pruned trees of the earlier varieties. Champion gave results so similar that it was not thought necessary to multiply photographs. Elberta is not included in this orchard, but in all probability its action would be the same.

To prune any variety of later ripening season than Greensboro after its crop is harvested would seem to be unprofitable. Is it feas-

FIG. 5, BELLE (of Georgia), 5 YEARS OLD
Pruned in early June

ible to prune Carman and all later varieties before their crop is gathered? What sacrifice of crop is involved?

Carman, Belle and Champion trees were pruned as described above in early June, July and August. In every peach tree there are shoots that do not bear, and others that grow so close together on the main limbs as to shade one another too much for good fruit development. In the case of these varieties the barren shoots, and a part of those placed close together, were pruned, leaving fruiting wood the whole length of the main limbs. In this way all the trees

produced as full a crop as they should. In all cases the early-pruned trees developed fruiting wood in the lower part of the crowns, as indicated in Fig. 5. The late-pruned trees, and the unpruned trees, gave much less fruiting wood, particularly in the lower part of the crown (see Fig. 6).

All peach trees tend to develop a stronger growth toward their outermost parts, whatever the pruning. This is seen in all the trees illustrated herein. But if the center of the crown is kept open, enough light will reach the lower parts to insure the development of a profitable crop, where in unpruned trees little or no fruit is produced. It is recognized that summer pruning involves additional expense to the

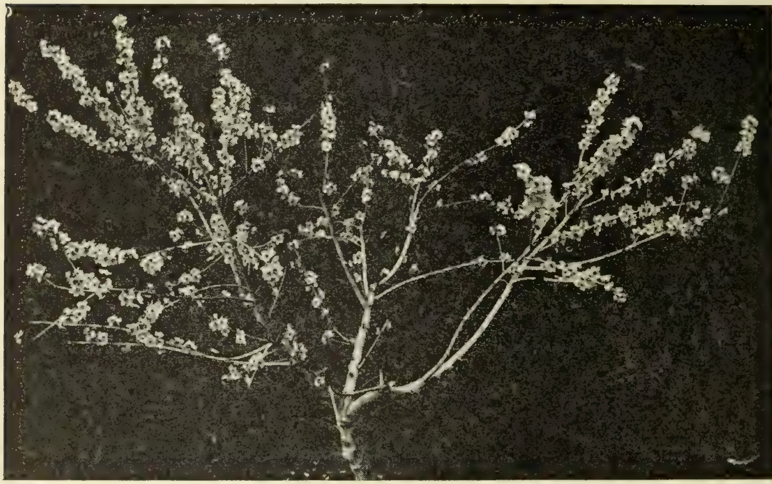

FIG. 6, BELLE, 5 YEARS OLD
Not summer-pruned

grower. But the method is quickly learned and cheaply employed. All that is necessary is to cut back the wood of the previous year's growth before the middle of June, and only in the inner part of the crown; the outer branches get enough light laterally. Fig. 7 is a fourteen-year-old Greensboro tree that was summer-pruned after its crop—a full one—was harvested in June, 1913. It has been dehorned twice, the last time in 1910. Its center has not been kept as open as in the trees previously illustrated, but there is a fine setting of bloom throughout the crown. Fully one-third of its crop is set within five feet of the ground, the total height of the tree being nine feet. Compare this tree with Fig. 8, in which the new wood was permitted to

grow unpruned throughout the summer of 1913; the practice of summer pruning, for early varieties, at least, would seem to be established.

Summer pruning will enable the grower to develop a full crop of fruit in the lower part of his late varieties if he trains the trees properly. Let us suppose a tree, open at the center, with fruiting wood well distributed along its main or skeleton limbs from the crotch to their ends. Young trees in which three skeleton limbs radiate from the trunk in spreading fashion will produce new shoots at close intervals. If these new shoots are pruned alternately, before the middle of June, one set being allowed to grow throughout the season and

FIG. 7, GREENSBORO, 14 YEARS OLD
Not summer-pruned

the other pruned to a spur, the following year the unpruned shoots will bear a crop. The second year they will be reduced to spurs and the alternate set will bear. Thus both late and early varieties can be kept in full bearing the entire length of their skeleton limbs. Even with this heavy pruning the greater convenience of harvesting and spraying the low-crowned trees will warrant whatever increased labor the plan involves.

When winter pruning alone is practiced heavy growth follows. Such new shoots as form on the lower parts of the crown reach up for light, and before midsummer are crowding one another so much

as to overtop completely the weaker growths. By fall these smaller shoots are dead, and because of lack of light very few fruit buds have formed on the lower parts of the surviving shoots. Thus the fruit forms toward the ends of the new wood, where it is poorly supported. As the crop approaches maturity these long branches bend and break beneath a weight of fruit that could have been safely carried had it been placed near their bases. Summer pruning evades this difficulty by thinning the new growth and giving the parts remaining full sunshine.

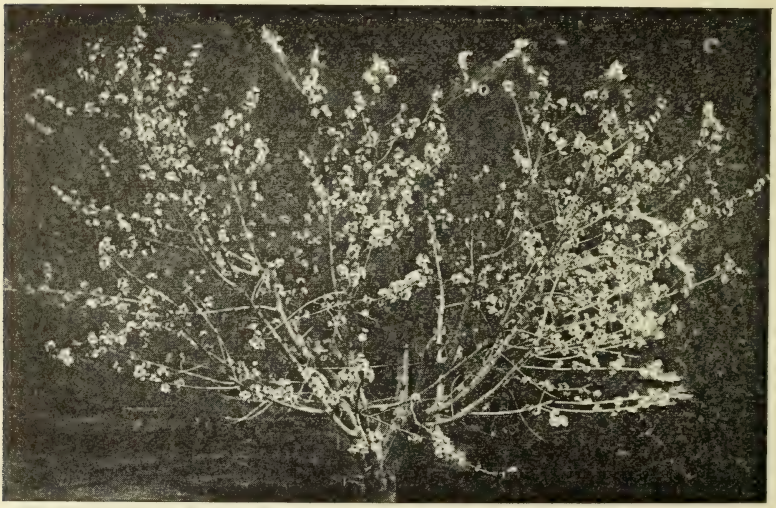

FIG. 8, GREENSBORO, 14 YEARS OLD
Summer-pruned immediately after harvesting of crop of 1913

Summer pruning is an insurance against sun-scald on the skeleton limbs of the trees; for the shoots that spring from the upper sides of the main branches not only shade them but draw into their supporting tissues a constant flow of sap, thus keeping them in vigorous health.

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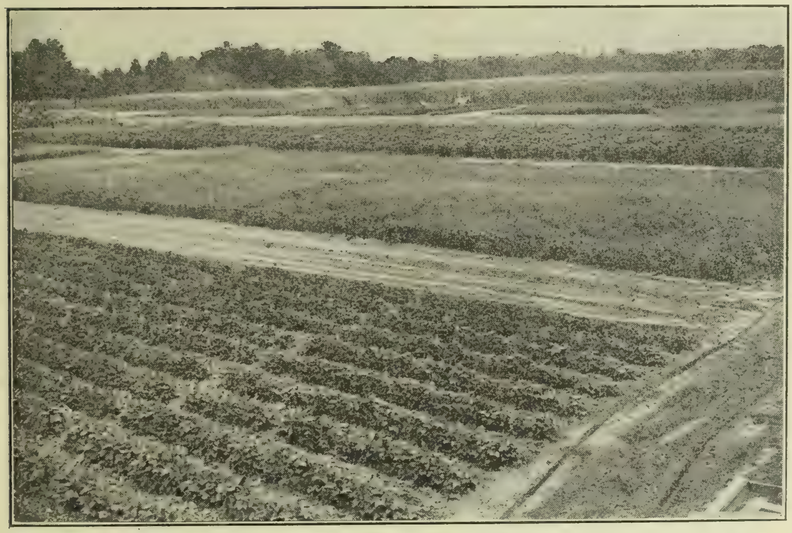
FERTILITY AND CROP EXPERIMENTS AT THE WEST TENNESSEE STATION

BY

C. A. MOOERS

ASSISTED BY

S. A. ROBERT



EXPERIMENTAL FIELD

KNOXVILLE, TENNESSEE.

The Agricultural Experiment Station

OF THE UNIVERSITY OF TENNESSEE

BROWN AYRES, President

The Experiment Station building, containing the offices and laboratories, and the plant house and part of the Horticultural Department, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy building, etc., are located one mile west of the University on the Kingston Pike. The fruit farm is adjacent to the Industrial School and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

FERTILITY AND CROP EXPERIMENTS AT THE WEST TENNESSEE STATION

BY
C. A. MOOERS
ASSISTED BY
S. A. ROBERT

THE SOILS USED FOR EXPERIMENTAL PURPOSES

The soils at the West Tennessee Experiment Station farm are silt loams such as are found over large areas in that part of the State. Two distinct types have been used in the experimental work. One may be described as a light, brown-colored silt loam with a yellowish-colored subsoil. This is naturally an excellent soil, easily handled and well adapted to a great variety of both farm and garden crops, but it has been greatly reduced in fertility by long continued cropping in cotton and corn. However, without manurial treatment, the yields of corn have run from 25 to 40 bushels per acre and of seed cotton from 700 to 1100 pounds. The other soil is of a gray-colored, "crawfishy" type, with a gray subsoil. This soil is very high in silt, does not drain readily, and is troublesome to handle. The part used for experimental purposes had good surface drainage and had been in Lespedeza, for which it is adapted, for a number of years, so that a fair supply of readily available nitrogen was present. Without manurial treatment the yields of corn have run from 28 to 37 bushels per acre and of seed cotton from 670 to 1030 pounds per acre.

The chemical analyses of these soils showed them to be very low in both total nitrogen and humus, medium in their supplies of available potash and lime, and poor in available phosphoric acid.

The experimental fields were laid off in the spring of 1909 and a large part of the permanent rotation and fertility experiments were begun at that time. The period since then is too brief, however, for conclusive data on many of the projects undertaken and this publication is intended to present only the most important of the practical results available at this time (January, 1914).

PHOSPHORIC ACID AND POTASH

A number of experiments have been carried out with the object of determining the need of phosphoric acid and potash by the Station's soils. The results obtained thus far with most farm crops do not show any great need of either of these elements of plant food. At the same time, the soils can not be said to be well supplied with them. In

the rotation of cowpeas and wheat on Range 3 neither phosphate nor potash has proved profitable at the end of a four-year trial, though a slight increase in yield of wheat can be attributed to them. In miscellaneous fertilizer experiments conducted for three years with spring oats no increase could be attributed to these materials whether used alone or in combination with nitrate of soda. In a five-year experimental crop rotation of cowpeas, wheat, clover, cotton and corn an annual application of 200 pounds per acre of acid phosphate and 50 pounds of muriate of potash proved unprofitable for all crops except cotton, the yield of which was increased by 263 pounds of seed cotton per acre. Also in the special fertilizer experiments with corn the combination of acid phosphate and muriate of potash was unprofitable, but in similar experiments with cotton was moderately profitable. Alfalfa was also appreciably benefited by phosphate. Evidently cotton and alfalfa are more sensitive to a deficiency of these elements than are other farm crops, and may be classed in this respect with the trucking crops.

LIME

BURNT LIME VERSUS LIMESTONE

Description of soils

Liming experiments in which both burnt lime, applied at the rate of 1 ton per acre, and ground limestone, applied at the rate of 2 tons per acre, were used, were begun in 1909. The trials were made in connection with some rotation experiments in which both of the soils mentioned were included. Experiments on the gray-colored "crawfishy" soil were conducted on two parallel ranges, called "A" and "B" in the table. On the brown silt loam the experimental ranges designated as "2", "3" and "4" were used.

Effects of Liming on Clover

Boys at left standing in clover where lime had been applied and on right where none had been used.

Table I—*Burnt lime vs. ground limestone. Experimental results obtained with various farm crops at the West Tennessee Station at Jackson—Soils: Ranges A and B, a gray-colored silt loam, very difficult to manage ("crawfishy" type); Ranges 2, 3 and 4, poor silt loam*

Crops	Range where grown	No. of plots averag'd	Year of harvest	Yield per acre				Increase per acre		Remarks
				Unlimed	Burnt lime	Unlimed	Ground lime-stone	Burnt lime	Ground lime-stone	
				Tons	Tons	Tons	Tons	Tons	Tons	In all these experiments the liming was done in the early spring of 1909. The burnt lime was applied at the rate of 1 ton per acre and the ground limestone at the rate of 2 tons per acre. Only 27 per cent of the latter was fine enough to pass through a 100-mesh sieve and 19 per cent was too coarse to pass through a 20 sieve.
Cowpea hay.....	A & B	22	1909	0.83	0.92	0.78	0.73	0.09	—0.05	
" "	2	22	"	0.95	1.66	0.94	1.48	0.71	0.54	
Soy-bean hay....	4	10	"	2.23	3.22	2.06	3.04	0.99	0.98	
Cowpea hay.....	3	24	1910	0.82	1.20	0.92	1.38	0.38	0.46	
Mixed sorghum and cowpea hay	4	6	"	1.87	2.65	1.85	2.77	0.78	0.92	
				Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	
Corn	A, B & 4	4	"	26.9	30.3	28.6	32.5	3.4	3.9	
Barley	4	16	"	12.7	17.3	12.4	17.2	4.6	4.8	
Wheat	2 & 3	26	"	9.5	13.5	11.6	14.8	4.0	3.2	
				Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
Cotton	A & B	10	"	884	788	1040	1028	—96	—12	
"	2	10	"	1500	1468	1276	1308	—32	22	
				Tons	Tons	Tons	Tons	Tons	Tons	
Cowpea hay.....	3	14	1911	1.08	1.23	1.26	1.28	0.15	0.02	
Soy-bean hay....	4	2	"	1.83	2.15	1.75	2.30	0.32	0.55	
Mixed sorghum and cowpea hay	4	4	"	1.26	1.46	1.31	1.37	0.20	0.06	
				Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	
Corn	A, B & 2	8	"	34.4	37.4	31.1	35.6	3.0	4.5	
				Tons	Tons	Tons	Tons	Tons	Tons	
Clover and grass.	A & B	12	"	2.36	2.52	2.16	2.70	0.16	0.54	
" " "	2	12	"	0.43	1.85	0.94	2.49	1.42	1.55	
" " "	4	10	"	0.85	2.99	0.86	2.89	2.14	2.03	

TABLE I—*Burnt lime vs. ground limestone. Experimental results obtained with various farm crops at the West Tennessee Station at Jackson—Soils: Ranges A and B, a gray-colored silt loam, very difficult to manage ("crawfishy" type); Ranges, 2, 3 and 4, poor silt loam—Concluded*

Crops	Range where grown	No. of plots averag'd	Year of harvest	Yield per acre				Increase per acre		Remarks
				Unlimed	Burnt lime	Unlimed	Ground limestone	Burnt lime	Ground limestone	
				Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	
Oats	A & B	6	1912	26.5	31.3	25.8	32.4	4.8	6.6	
"	2	6	"	44.6	49.4	30.6	40.9	4.8	10.3	
Wheat	3	9	"	22.9	29.6	19.8	24.7	6.7	4.9	
				Tons	Tons	Tons	Tons	Tons	Tons	
Cowpea hay..	2	10	"	0.96	1.02	0.81	1.04	0.06	0.23	
" "	3	18	"	0.88	1.55	0.91	1.70	0.67	0.79	
" " ...	A & B	10	"	0.75	0.80	0.70	0.83	0.05	0.13	
Sorghum and cowpea hay	4	6	"	2.06	3.33	2.47	3.65	1.27	1.18	
				Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	
Cotton	2	12	"	1184	1287	1430	1419	103	—11	Red clover the preceding crop, but clover little benefited by liming on A & B.
"	A & B	12	"	1188	1157	1002	912	—31	—90	

Both the burnt lime and the ground limestone were strictly high-grade. The mechanical analysis of the latter was as follows:

Particles retained by a No. *20	sieve	19.3	per cent
" " " " 40	"	27.1	"
" " " " 60	"	14.2	"
" " " " 80	"	7.6	"
" " " " 100	"	4.4	"
" that passed through " 100	"	27.4	"
		100.0	"

DISTRIBUTING GROUND LIMESTONE

DISCUSSION OF RESULTS

Results on Ranges A and B

In the trials on Ranges A and B five distinct kinds of farm crops have been grown in the four years which have passed since liming. These crops are as follows: Cowpeas, corn, cotton, clover and grass, and oats. On this soil the effect of either form of lime on the cowpea crop was practically nothing, there being a slight apparent gain from the burnt lime and a slight apparent loss from the ground limestone. The yields of corn for 1910 show, however, an evident increase, amounting to 3.4 bushels per acre for the burnt lime and 3.9 bushels per acre for the ground limestone. The 1911 corn crop shows 3.0 bushels per acre increase from burnt lime and 4.5 bushels increase from the ground limestone. Excellent crops of red clover

*By a No. 20 sieve is meant a wire sieve having 20 square openings per linear inch, or 400 per square inch. In like manner "40", "60", etc., refer to the number of openings per linear inch.

were obtained without the aid of lime; in fact, the effect of liming was scarcely evident to the eye. The yields show, however, 0.16 ton per acre increase from burnt lime and 0.54 ton increase from the ground limestone. The cotton crop of 1910 appears to have been injured by liming rather than benefited, the decrease of seed cotton attributable to the application of burnt lime being 96 pounds per acre and that due to the ground limestone 12 pounds per acre. The oat crop of 1912 was appreciably better on the limed than on the unlimed sections, the increase attributed to the burnt lime being 4.8 bushels per acre and to the ground limestone 6.6 bushels per acre. The cowpea crop of 1912 was only slightly benefited by either form of lime, and again in 1912 the cotton crop was somewhat reduced by each.

Results on Ranges 2, 3 and 4

On Ranges 2, 3 and 4 the five crops tested on Ranges A and B were grown, and in addition the four following: Soy beans, wheat, barley, and a mixture of sorghum and cowpeas for hay. An examination of Table I will show that both forms of lime gave markedly increased yields for all the crops except cotton, and it is evident from these results that a direct application of lime may be detrimental to this crop, which behaves in strong contrast to all the others. The most favorable effects of liming were noticeable on the clover, which, in fact, was a complete failure where unlimed, even on those plots which were well dressed with stable manure. The next most noticeable results were obtained with soy beans, the yields of hay being increased nearly one ton per acre from either form of lime.

Burnt lime versus ground limestone

An important feature of these experiments consists in the comparative returns from burnt lime on the one hand, and from ground limestone on the other. A study of Table I shows that the returns are very close. If the increased yields of all hay attributable to liming be summed up, we find an average increase for each crop harvested of 0.67 ton per acre for the burnt lime and 0.69 ton per acre for the ground limestone. If the increased yield of all kinds of grain crops be averaged in a similar manner we find an average increase of 4.5 bushels for the burnt lime and 5.5 bushels for the ground limestone. We would conclude, therefore, that in these trials 2 tons of ground limestone proved somewhat superior to 1 ton of burnt lime.

NITROGEN

All of the soil fertility experiments indicated a great deficiency of nitrogen. Such crops as corn, oats, wheat and cotton were found to be materially increased by the light application of 100 pounds per acre of nitrate of soda. Such an application proved profitable for the first three crops only when the season was favorable, but for cotton profitable returns were the rule. In a four-year series of experiments two

plots, receiving each year an application of 200 pounds of acid phosphate and 50 pounds of muriate of potash per acre, averaged 1133 pounds of seed cotton, but two adjoining plots, which received 100 pounds per acre of nitrate in addition to the phosphate and potash, produced an average yield of 1407 pounds of seed cotton. During the same period the average yield of two unfertilized plots was only 948 pounds of seed cotton per acre.

The green-manure experiments demonstrated the great need of nitrogen, the effect of a legume turned under being very marked on the grain crop which followed.

TIME OF APPLICATION OF NITRATE OF SODA

Nitrate of soda—value and properties

Nitrate of soda furnishes nitrogen in its most available form for plant-food purposes. It is also about the cheapest commercial source of fertilizer nitrogen. These two reasons are sufficient to warrant the study on the part of every farmer of the most important principles concerning its use. Nitrate of soda is very readily soluble in water and may be lost from the soil by leaching, but this chance of loss is much less than might be supposed, as the results of Table II show. It may be decomposed and nitrogen be lost into the air by being mixed with acid phosphate, but in practice such loss is apt to be small. Nitrate takes up moisture from the air in considerable quantity, and the mixture with acid phosphate is liable, if sufficient nitrate be present, to become sticky, so that there are two reasons against mixing acid phosphate and nitrate of soda. Fertilizer manufacturers have found, however, that they could add a small amount to their mixture without bad results, and this is not an uncommon practice. Because of the chance of loss by leaching and of the possible bad results from mixing with other fertilizer materials, nitrate of soda is usually applied by itself as a top-dressing. The generally accepted rules in regard to its use are as follows:

Rules for use of nitrate

1. If the soil be poor in either phosphoric acid or potash, nitrate should not be used until the deficiency in these mineral elements is supplied. According to numerous trials on poor soils in this State, 300 pounds of acid phosphate and 50 pounds of muriate of potash are ample to reinforce 160 pounds of nitrate.

2. For fall-sown small grains, a very light application—say 40 pounds per acre—may be made at the time of seeding, provided the soil be poor and there be some danger of the crop's freezing out; otherwise all of the nitrate is applied as soon as spring growth starts, or sometime in March. For spring and summer crops the nitrate is applied as a top-dressing when the plants are small.

3. Nitrate should not be applied when the leaves of the plants are wet with rain or dew, as burning is apt to follow.

TABLE II—*Experimental results relating to time of application of nitrate of soda*

Crop	Exp. No.	Amount of nitrate applied per acre	Time of application of nitrate	Yield per acre		Remarks
				Grain Bu.	Stover Ton	CORN
Corn	1	None	.....	25.7	1.19	The average of three complete sets conducted on three different farms, each in a different section of the State. Phosphate and potash used on all plots alike.
	2	100 lbs.	When plants about 3 in. high	31.2	1.39	
	3	"	" " " 2 ft. "	31.4	1.32	
	4	"	" " " 3½ " "	30.0	1.25	
	5	"	As soon as in tassel	24.8	1.26	
				Salable tubers Bu.	Culls Bu.	POTATOES
Irish potatoes	1	None	.....	78	14	Average of four sets on four different farms, three on Cumberland Plateau and one on Highland Rim. Phosphate and potash used in ample amount to balance nitrate.
	2	320 lbs.	Mixed in row before planting	145	22	
	3	"	In one application as soon as plants came up	150	16	
	4	"	In two applications, ½ as soon as plants up and ½ about 12 days later	133	20	

4. With light applications, up to, say, 200 pounds per acre, all the nitrate may be applied at one time, but with heavy applications one-half is often advised to be applied at an early stage of growth and the balance in ten days or two weeks.

EXPERIMENTAL EVIDENCE

For the reason that there is at the present time a wide difference between the recommendations of some writers in regard to the time at which nitrate should be applied, experiments were undertaken on this subject with two crops,* corn and Irish potatoes. The soils used were, of course, deficient in nitrogen in each case, and phosphate and potash were applied in ample quantity to make the nitrate effective. Table II gives the schemes followed and the results obtained as an average of several trials for each crop.

DISCUSSION OF THE RESULTS

Early application best for corn

The results with the corn point very definitely to the application of the nitrate at an early stage of growth, the gain being greatest when the plants were from 3 inches to 2 feet high. Of special interest were the results following the application made at tasseling time, for in none of the three series from which the averages were obtained did any increase in yield of grain result from this time of application, the only apparent effect being a deeper green foliage.

Early application best for potatoes

The results of the experimnts on Irish potatos are of special interest, as three of the four sets were made on the fine sandy loams of the Cumberland Plateau, which might be expected to suffer from leaching. In practically every one of the four sets nearly as good results as any were obtained when the nitrate was mixed with the phosphate and potash applied in the row before planting. This was rather unexpected, for the rainfall at this time of the year is heavy, so that loss of nitrate would be looked for. The results from applying one-half of the nitrate as a top-dressing when the plants were just coming up, and the balance in ten days or two weeks, were unfavorable to this method. As with the corn, the results are, therefore, decidedly in favor of an early application.

GREEN-MANURE CROPS

Numerous experiments have been conducted at this Station to determine the effects both of legumes, such as cowpeas and crimson clover, and of non-legumes, such as corn, sorghum and rye, when turned under for green manure, on the yield of the immediately fol-

*Only a single series, with corn, was conducted at the Jackson Station. The others were conducted in Middle Tennessee.

lowing crops of corn and wheat. The results may be summed up as follows:

Non-legumes 1. Corn, sorghum and millet are not suitable crops to be grown for green manure. The yield of corn immediately following them was considerably reduced. Rye is advised, however, as a winter cover crop, but should be turned under early, when about one foot high, or less.

Legumes 2. The legumes can be advised as green-manure crops, but cowpeas and soy beans when used for this purpose are not apt to be profitable for the first few years. If turned under each year and followed with wheat or other small grain, as can be done successfully at Jackson, the effect is cumulative; that is, the area where the cowpeas are turned under, gradually increases in productiveness, while the area where either the peas are removed for hay or no peas are grown gradually becomes poorer until the difference between them is very marked. In the last two years of a five-year trial there were obtained from 4 to 9 bushels per acre more of wheat on the area where the cowpeas were turned under than where either none were grown or the crop was removed for hay.

Sweet clover Sweet clover sown April 11, 1912, was cut once that year for hay and was turned under May 13, 1913, and followed with corn, which made a yield of 58.8 bushels per acre. On an adjoining plot, where rye was turned under, the yield of corn was only 41.1 bushels. Sweet clover used in this way is a valuable crop, but it should be sown only on land well supplied with lime, and soil inoculation is necessary at the outset the same as for alfalfa. Also mention should be made of the fact that according to our trials fall seeding has not given good results.

Crimson clover Crimson clover is a very valuable green-manure crop, which may be sown in early fall and be turned under previous to the planting of either corn or cotton. This crop is not so sensitive to a deficiency of lime as either sweet or red clover, but is generally benefited by liming. Unfortunately, a stand is not apt to be obtained when the seed is sown at the last working of corn, cotton, etc. It may be sown to advantage after spring and summer trucking crops and after wheat or other small grain, and even after corn removed early for silage or the like.

Bur clover Bur clover may be used in much the same way as crimson clover, but requires a good supply of lime, and inoculation may be necessary, at least if the clean seed be used.

Hairy vetch Hairy vetch seed is expensive, but may be sown in cotton and sown later than crimson clover. It does not, however, make much growth during the

fall and winter, and to give best results it must be turned under several weeks later than crimson clover.

Japan clover

In this connection the great value of Japan clover both for pasture and green manure should not be overlooked, and though it comes in naturally in the course of time, seed may be sown with great profit in order to hasten a full stand over the field.

ALFALFA

Experiments have been made with alfalfa on both the brown and the gray soil. The results proved that with attention to its special requirements alfalfa could be grown successfully on either type.

Liming necessary

Liming was a necessity, but the results proved that a very heavy application was not needed. In fact, 2 tons appeared to be ample, and according to trials at the Knoxville Station would be expected to be sufficient for eight or ten years. In order to get the limestone well mixed throughout the soil it may be applied and well disked into the soil before plowing.

Phosphate important

An abundant supply of phosphate is of much importance. In the experimental work 500 pounds or more of acid phosphate has been used per acre as a supplement to the manure. This is rather heavy phosphating, but 500 pounds furnishes no more phosphoric acid than would be removed by 10 tons of alfalfa hay. The thorough mixing of the phosphate with the soil is essential to the best results. At least in the case of a very heavy application one-half may well be applied and disked into the soil before plowing and the other half afterward.

Potash may be of value

Potash did not always prove necessary—perhaps due to the amount of manure used—but 100 pounds per acre of muriate of potash is advised, and may be applied along with the acid phosphate.

Manure of much value

Farmyard manure is a great help in getting a stand of alfalfa, even on rich land, and on very poor land should be considered a necessity. Twelve tons per acre were found to be ample. It is well to make the application early in the season, so that weed seeds may have a chance to sprout and be killed before the alfalfa is sown. Undoubtedly the manure may be reduced in quantity or even omitted if green-manure crops, such as crimson clover, sweet clover, etc., are grown in preparation.

Inoculation necessary

At the Knoxville Station, and occasionally elsewhere, soil inoculation is not required, but in the majority of instances it is a necessity, as was the case at Jackson. Certainly the risk of fail-

ure is too great for inoculation to be omitted the first time that a field is sown. The most certain plan is to use, say, 300 pounds per acre of soil from an old alfalfa field where the nodules were abundant on the roots of the plants. The inoculating soil may be screened and drilled in like fertilizer to advantage, but if scattered broadcast a cloudy day should be selected and the application should be harrowed into the ground.

Late summer or early fall seeding best

The best time of seeding is the latter half of August or early in September—early enough so that the plants will go through the winter without being frozen out. Wheat or other small grain, or Irish potatoes, may precede alfalfa, but a summer crop is apt to leave the ground so dry that the necessary fall growth can not be made. The best plan, therefore, is to turn the land in June, or as early in July as possible, and keep well harrowed in order to destroy weeds and to provide a moist and mellow seed-bed.

Amount of seed

Twenty-four pounds of seed per acre—twelve pounds sown each way—is advised unless the soil and seasonal conditions be very favorable. A heavy seeding is necessary in order both to crowd out weeds and to allow for the thinning of the stand, which always takes place, due to disease, weeds, losses by harrowing, etc.

Nurse crops and reseeding

Nothing in the way of a "nurse crop" should be used, the results of the experiments showing that the greater the "nurse crop" the less was the alfalfa. Spring seeding is justifiable, and can be recommended for one purpose only, and that is, to thicken a poor stand obtained the previous fall. Attempts to thicken a stand two or more years old have, in our trials, always failed.

Harrowing necessary

Two weeds have proved to be especially troublesome in alfalfa culture; one is crab-grass, which flourishes only in the summer, and the other is chickweed, which is dangerous only in the winter. In either case, harrowing with a specially constructed alfalfa harrow is the remedy. Harrowing should be done after every cutting, beginning with the first one in the spring. In this way alfalfa at the Station farm has been kept free of crab-grass for the past five years.

Time of cutting

Cutting is recommended as soon as the new shoots at the base of the plants are from 2 to 3 inches long. In very dry weather the yellowing of the leaves may indicate that cutting is advisable even though the growth be very small.

Top-dressing

In order to maintain a stand on average upland, a top-dressing of manure or fertilizer, or both, may be necessary about the third season. Eight or ten tons of manure per acre may be applied in late winter or in

early spring. Preferably the manure from cattle fed on silage and cottonseed meal should be used both because of its richness and because of its freedom from weed seeds. Six tons of manure and 200 pounds of acid phosphate per acre would also be a fair application. If fertilizer alone be used, a mixture of 300 pounds of acid phosphate and 100 pounds of muriate of potash is recommended, to be applied at the same season as advised for the manure.

"CLOVERS"

RED CLOVER

Of all the legumes red clover may well be considered as the most valuable for soil-improvement purposes, and although some soils may not be naturally adapted to this crop, the aim of every farmer should be to get his soil into the proper condition for its profitable production. Liming is apt to be the main requirement, but for poor land there must usually be given, in addition, at least a light dressing of

Red Clover on "Crawfishy" Land

manure, or there may be turned under for one or more seasons beforehand such green-manure crops as can be grown to most advantage. According to common farm practice, seeding is nearly always done in the early spring, with some nurse crop, such as wheat or oats, but the Station's experimental results have demonstrated that where the success of clover is rather uncertain, seeding without a nurse crop in the latter part of August or early in September is advisable. Indeed, in this way the best crops can be obtained on almost any soil. The land should be plowed early in the summer and kept well harrowed to destroy weeds and conserve the moisture supply, so that a stand can be obtained at the proper time. Red clover has done exceptionally well

on both the gray and the brown soil, but for the latter liming was an essential to success.

ALSIKE

Alsike clover is not so robust as red clover, and is, therefore, not so well suited to poor land. It has, however, done very well in our experiments, and has some advantages over red clover, especially in that it is completely resistant to the common red clover disease, which has done great damage throughout the State during the past twenty years or more. Only about two-thirds as much seed is required as for red clover. In experiments on the brown soil alsike sown in the early fall made good cuttings for two years, but red clover sown at the same time lasted only one year.

CRIMSON CLOVER

Crimson clover is a valuable green-manure crop, but only rather fertile soils are well adapted to it. For best results it should be sown by itself in middle or late summer, but under favorable conditions it may be sown in September. According to the Station's experiments seeding in corn at the last working is not apt to be successful. In the experimental trials crimson clover proved to be disappointing at first and was easily surpassed by red clover. Later it was profitable, but for some reason has never done extra well.

LESPEDEZA

Lespedeza, or Japan clover, is not a true clover, but may be included with the others for practical purposes. Although found growing almost everywhere, it responds favorably to liming, as demonstrated on the Station plots. Under some conditions the seed may be sown with profit. This may be done in March or early in April. About 25 pounds per acre is required for a full stand the first year. Ten pounds, however, will be sufficient to give it a good start.

MELILOTUS

Melilotus, or sweet clover, is a legume but not a true clover. This plant, like alfalfa, requires a soil well supplied with lime; also soil inoculation with the same kind of bacteria required by alfalfa is apt to be necessary. It is probable that with attention to liming and inoculation, sweet clover can be used to some advantage as a green-manure crop. Twenty-five or thirty pounds of seed per acre is recommended, and spring seeding has given the best results. It may be sown either alone or with oats as a nurse crop. The white-flowering variety rather than the yellow-flowering is recommended.

SOY BEANS

Soy beans and inoculation

Soy beans may be grown to advantage both for hay and for grain, and have greater capacity for making heavy yields than the cowpeas. The writer has sometimes observed that soy beans

when grown for the first time do not appear to be well inoculated, as indicated both by the light color of the foliage and also by the sparsity of the nodules on the roots. Continued growing of the beans on the same land would be expected to remedy the trouble, but soil inoculation may occasionally be advisable.

Soy bean varieties On the experimental ranges only the late and vigorous varieties, such as Mammoth Yellow, Tokio, and Acme, did well. The early varieties, such as Ito San and Haberlandt, which have done extra well at the Knoxville Station, made only a dwarfed and meager growth, such as is characteristic of the plants on poor land.

For a more complete comparison between the cowpea and the soy bean, reference may be had to Bulletin 82 of this Station.

Fertilizers Liming proved to be very beneficial to both soy beans and cowpeas at the Jackson farm. A complete commercial fertilizer for these crops need contain only acid phosphate and muriate of potash, say 200 pounds per acre of the former material and 20 pounds of the latter; but no gain from these materials was obtained in the experiments tried.

Tall Oat Grass—First Year After Seeding

GRASSES

The growing of grass should be considered one of the essentials to the most successful farming. Redtop is the common and generally most profitable grass, but a mixture containing Timothy is often sown on the more fertile soils. A number of experimental trials were made

with these and other grasses, and both orchard and tall oat were found to do well, the latter variety in particular having a great capacity for hay production. The best results were obtained from late August or early September seeding, and without a nurse crop. For hay a mixture of 33 pounds of tall oat-grass and either 12 pounds of red clover or 8 pounds of alsike per acre are recommended. Both lime and phosphate are generally essential for best results, and a light top-dressing of manure is very helpful. Clover not only adds to the yield but nourishes the grass. In the event of a failure of the clover, or after it has run out, a seeding of Japan clover may prove advantageous. In the absence of both clover and manure the grass may be top-dressed with 80 or 100 pounds of nitrate of soda per acre, and this light application was found to make the difference between success and failure.

SECOND-YEAR CLOVER AND GRASS

Tall oat-grass and alsike clover — Tall oat-grass and red clover — Tall oat-grass alone

COTTON

FERTILIZERS

Cotton is one of the few crops that were found to respond profitably to an application of both phosphoric acid and nitrogen. In the case of the plots where cotton was grown each year for four years the unfertilized plot gave an average yield of 948 pounds of seed cotton per acre, the plot that received 200 pounds of acid pohsphate and 50 pounds of muriate of potash per acre each year gave an average yield of 1133 pounds, and a third plot, which received 100 pounds of nitrate of soda per acre in addition to the 200 pounds of acid phosphate and 50 pounds of muriate of potash, gave an average yield of 1407 pounds

of seed cotton. Where cotton was grown once in a five-year rotation the average yield of two plots which received neither phosphoric acid nor potash was 1155 pounds of seed cotton per acre, but the average yield of two plots which received an annual application of 200 pounds of acid phosphate and 50 pounds of muriate of potash was 1417 pounds per acre. These results indicate that cotton is much more sensitive to a deficiency of the mineral elements than most other farm crops, for no other crop grown in the rotation responded in this manner. On the other hand, the effect of liming was very markedly beneficial on all of the crops, except cotton, the yield of which was little if any increased by it. Liming proved indispensable to red clover.

As a result of the experiments, the following fertilizer mixture can be recommended per acre for cotton:

200 lbs. acid phosphate
20 " muriate of potash
250 " cottonseed meal

The ingredients should be shoveled over until the mixture is of a uniform color. The application is best made in the row a few days before planting. Instead of the cottonseed meal, 100 pounds of nitrate of soda may be used, but the nitrate should not be mixed with the other materials but applied separately as a top-dressing along the rows when the plants are small, say one foot high, or less.

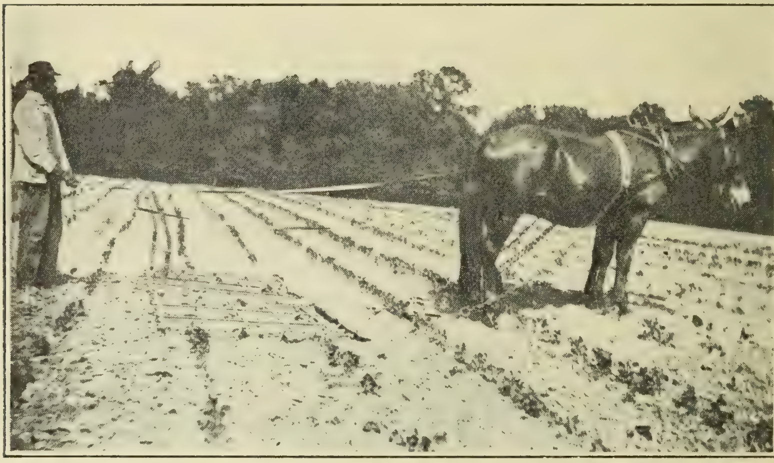
TABLE III—*Variety trials of cotton—average yield of Trice 1622 pounds seed cotton per acre*

Trice in comparison with	Number of years tested	Number of years in favor of Trice	Average yield per acre in favor of Trice Lbs.
Acala	3	3	204
Christopher's	3	2	89
Cleveland	3	1	—14
Columbia	4	4	349
Cooke's Prolific	3	3	205
Hawkins	3	3	172
Keenan	2	2	422
King	4	4	135
Russell	3	2	80
Simpkin's Early	3	3	128
Toole	3	3	315
Triumph	4	4	576

VARIETIES

A summary of the variety trials of cotton is given in Table III. As for corn, longer-continued experiments will be necessary before permanent conclusions are warranted. Trice cotton has proved, how-

ever, to be an early variety of great promise. The stalk is small and the boll medium large. The stock from which this variety has developed was found on the farm of Mr. Luke Trice, Henderson, Tenn. It is said to have come originally from Southern Missouri and has been used as a basis for improvement in selection and breeding by Prof. S. M. Bain, of this Station. Cleveland Big Boll gave a slightly greater average yield than any other variety. This variety has done well in Arkansas, Mississippi and Northern Louisiana. It is a little later than Trice, and produces a larger stalk, but is evidently a very valuable upland cotton.



Cross-harrowing Soy Beans

CULTURE

Plowing Either fall or early winter plowing, leaving the land rough, is best for cotton. Early plowing reduces insect pests and makes a mellow soil. Late March or early April plowing may, however, be advisable for land in a cover crop, such as crimson clover or rye, especially if the soil be light rather than heavy and difficult to prepare. Deep plowing, 7 or 8 inches, is urged instead of the not uncommon 3 or 4 inches.

Ridging Two or three weeks before planting time the land should be harrowed, the rows laid off, and the phosphate or mixed fertilizer applied, after which low ridges may be made at the distance apart desired for the rows. These ridges are important for soils which do not absorb heavy rains readily, for both the cottonseed and the plants should be kept out of standing water. Also the ridges hasten the drying out of the soil and the earliness of planting. A convenient and rapid method of

making the ridges is by means of the two-horse disk cultivators. Early preparation of the ridges makes a firm seed-bed, which is favorable both to a uniform depth of planting and to early germination of the seed. Ridges are of course unnecessary and even inadvisable in the case of an open soil which drains very readily. Just before planting, the surface 1 or 2 inches of the bed should be well pulverized by harrowing.

Width of rows

The width of the rows and the distance apart of the plants in the row depend first of all on the fertility of the soil. The richer the soil the wider should be the rows and the smaller the number of plants per acre. A general rule is that the distance between the rows shall be somewhat more than the expected height of the plants. For example, if the plants are apt to be 2 or 3 feet high the rows should be about 3½ feet apart and the plants 15 to 20 inches apart in the row. If 3½-foot plants are expected the rows should be 4 feet apart and the plants 20 to 24 inches apart in the row.

Planting

The depth of planting should be shallow, not over 1 inch as a rule. For planting on ridges the one-horse walking planter is most satisfactory. Usually an excess of seed is planted. Three pecks of seed per acre is considered ample. Rolling the moistened seed in dust, ashes or the like may be necessary in order to insure regular distribution. Cotton is strictly a warm-weather crop, so that extra early planting should be avoided. Any time from May 1 to 15 is recommended under Tennessee conditions.

Cultivation

The first cultivation may be given shortly after planting by running a section harrow once or twice across the rows. When a stand has been obtained the same kind of harrow, but with the teeth slanting well backward, may be run diagonally across the rows, and about a week later the operation may be repeated in the opposite direction. The weeder may be preferred to the harrow on a light soil and is always to be used instead of the harrow on a sandy soil. A few plants may be killed by this kind of cultivation, but no serious injury is done to the stand. which is thinned to the desired rate with the hoe, preferably by two thinnings. These early cultivations make unnecessary the common practice of "barring off" or cutting the soil away from each side of the plants, which are left on a narrow ridge. The later cultivation depends in part on the soil and season. An early deep working with a double-shovel or similar implement is often advisable, especially if the rains have compacted the soil or if grass and weeds have gotten the ascendency; otherwise only shallow cultivation, about 2 inches deep, is advised throughout the season. The cultivation is most economically done with a two-horse cultivator, using four or more shovels to a gang, but either a one-horse spring-tooth cultivator or a one-horse five-

shovel cultivator may be used. Also the two-horse disk cultivator is a highly valued implement in many places. A cultivation should generally be given every week or ten days until the fruit is setting; afterward an occasional cultivation may be given until the bolls are well formed.

CORN

TILLAGE

Experiments in methods of tillage of corn were conducted for three seasons. Each year four methods were compared, as follows:

Method 1. No cultivation, but weeds scraped off with hoe.

Method 2. Shallow cultivation, 12-tooth cultivator used throughout the season.

Method 3. Deep cultivation, double-shovel used according to common custom.

Method 4. First cultivation deep, with double-shovel, but after-cultivations shallow.

The average results for the three seasons' trial as given in Table IV show that Method 4 gave the highest yields, with Methods 2, 3 and 1 following in order.

TABLE IV—*Corn, tillage experiments—average yields from three seasons' trial*

Experiment No.	Method of cultivation	Yield of grain per acre Bu.
1	No cultivation, but weeds scraped off with hoe	37.7
2	Shallow cultivation, 12-tooth cultivator used throughout season	40.9
3	Deep cultivation, double-shovel used throughout season	38.9
4	First cultivation deep, but after-cultivations shallow	42.7

FERTILIZERS AND MANURES

None of the commercial fertilizers proved of practical value for corn on either the brown or the gray type. The only one that produced an appreciable increase in yield was nitrate of soda; but at the present prices of both corn and nitrate, the margin of profit was too little for it to be recommended.

As an average of four years' trials 5 tons of farmyard manure raised the yield from 38.0 to 46.5 bushels per acre.

Liming increased the yield on both types of soil, but more on the brown than the gray type. The average increase attributable to

liming in the case of the brown soil was 5.5 bushels of corn for each of the four years following the application.

For the benefit of those who may have a soil which responds to phosphating, the following formula is given for corn, sorghum, millet, etc.:

150 lbs.	16 per cent	phosphate
10 "		muriate of potash
100 "		cottonseed meal

The total of 260 pounds is considered a practical amount for one acre. The mixture analyzes as follows:

Available phosphoric acid,	9¼	per cent
Nitrogen	2½	" "
Potash	2	" "

This formula was gotten as a result of experiments on soils very poor in phosphoric acid, such as are found on the Highland Rim of Middle Tennessee.

TABLE V—*Variety trials of corn at the West Tennessee Station (average annual yield about* 40.0 *bushels per acre)*

Lewis Prolific in comparison with	Number of years tested	Number of years in favor of Lewis Prolific	Average yield per acre in favor of Lewis Prolific Bu.
Albermarle Prolific............	5	4	1.8
Boone Co. White..............	3	2	2.5
Cocke's Prolific................	3	3	6.0
Hawk's	3	3	5.4
Hickory King.................	5	3	*5.9
Hildreth (Kansas seed)........	3	2	2.6
Huffman	5	3	1.9
Iowa Silver Mine..............	3	3	7.2
Kansas Sunflower (Kan. seed)...	3	2	3.6
Leaming	2	2	9.3
Legal Tender (Kansas seed).....	2	1	5.4
Little Willis..................	4	3	1.1
Looney	4	3	4.9
Matthews	3	2	2.6
Overall	2	2	5.6
Reid's Yellow Dent............	5	5	4.7
Webb's Improved Watson......	5	5	8.5
No. 182.....................	2	2	1.9

* Almost entirely due to the very low yield of Hickory King during a single season, that of 1911. With this season eliminated the average yield in favor of Lewis Prolific was only 1 1-4 bu. per acre.

VARIETIES

The testing of varieties is neither a brief nor a simple matter. Differences in season and soil are such important factors that in gen-

eral long-continued experiments are necessary from which to draw permanent conclusions. In particular, soil fertility has much to do with the choice of varieties, for those best suited to rich land are not apt to do best on poor land.

The trials reported in Table V were made on land above the average for West Tennessee in productiveness, the average yield of the leading varieties being in the neighborhood of 40 bushels per acre. This yield was due in part to the rather liberal use of commercial fertilizer—200 or 300 pounds of acid phosphate and 100 pounds of nitrate of soda per acre.

The results given in the table can not be considered as conclusive —the period of trial is too short for that—but the data are the best we have for this part of the State at the present ime. Lewis Prolific, a variety developed by E. M. Lewis, McKenzie, Tenn., proved to be a leader, and is used as a basis of comparison for the others.

According to these trials, the following varieties are the most promising for common uplands:

Lewis Prolific
Hickory King
No. 182 (a Government selection of much promise)
Litle Willis

For rich land, Huffman, Albermarle Prolific and Hildreth are especially heavy yielders.

THE SMALL GRAINS

WHEAT

Wheat enters very nicely into most systems of crop rotation, and both the climatic and soil conditions of West Tennessee are favorable to it. The placing of this crop after corn should as a rule be avoided, although this may be done on soils of good fertility, especially if the corn be cut and shocked or removed for silage. Either cowpeas or soy beans, if removed early for hay, make an excellent preceding crop.

Best varieties

According to Station trials, which have been continued for several years, the best varieties of wheat for average uplands are Fulcaster, Mediterranean, Poole and Currell's Prolific. For rich land, where the other varieties are apt to lodge, Fultzo-Mediterranean has proved superior to any other.

Fertilizers

If the wheat be preceded by cowpeas, soy beans, or one of the clovers, or if a dressing of farmyard manure be made, then only acid phosphate at the rate of, say, 200 pounds per acre is advised as a fertilizer. Otherwise a complete fertilizer, such as recommended for corn, may be used. Under some circumstances a light dressing of, say, 40 pounds per acre of nitrate of soda may be profitably made in the fall, especially if the seeding be unduly delayed. Under usual conditions 60 to 100 pounds of nitrate may be applied in the spring, as soon as early

growth starts, but the margin of profit is not great. Cottonseed meal, dried blood, nitrate of soda, and other active forms of nitrogenous fertilizer are detrimental to the germination of seed with which they come into direct contact, and the later and more unfavorable the season the more pronounced is this effect. If any one of these materials be used, therefore, it should be drilled in separate from the seed. Acid phosphate, however, does not injure the germination, so that when used alone no precaution is necessary.

OATS

Both spring and winter oats were grown successfully, but the results indicate that whenever possible winter rather than spring oats should be used. The Station at Knoxville found that the Culberson variety had some very desirable qualities, and has obtained from it a short-strawed selection which rarely lodges even on extra rich land, matures nearly two weeks earlier than the Turf oat, and is equally productive of grain. It has done well at Jackson.

Best varieties

The Burt and the Kherson, or 60-Day Russian, are the best spring varieties. The latter is only two or three days later than the former, produces somewhat more foliage, and has given, in comparative trials at Jackson, a better yield of grain than the Burt.

Time of seeding

According to our date-of-planting trials, winter oats should be sown earlier in the fall than any other small grain, or about the middle of September. Spring oats should be sown as early in the season as possible.

Oats and clover for hay

A mixture of Culberson oats and either red or alsike clover for hay has been tried experimentally with excellent results. A full seeding of each is advised, and the seeding should be done early in September.

TENNESSEE WINTER BARLEY AT STATION FARM

BARLEY

Winter barley is a rich-land crop, which does extra well on land too fertile for wheat. It is not, therefore, well suited to average soils. However, on account of its ready response to manuring, and its great capacity for grain production, it should receive more attention than in the past. Seeding should be done the latter part of September in order to give the best results.

Spring barley is of little value, and has not proved equal to spring oats.

RYE

Rye is valuable chiefly as a grazing, soiling, and cover crop, and also as a green manure on very poor land. It can be sown with good results fully as late as wheat, November seedings being successful. October is probably the best month for seeding, but it is often sown in September for pasture purposes. On the experimental ranges it proved to be an excellent winter cover crop.

SORGHUM

The saccharine, or sweet, sorghums have long been grown both for forage and for syrup. The common Redtop variety is well adapted to forage purposes, but the juice is too dark to make the best syrup. Tennessee-grown seed has proved to be superior to Western-grown seed. Amber, Orange, and other varieties are often grown for syrup-making purposes. Recent experiments by the Station have indicated, however, that the Honey variety, which is equally adapted to forage and to syrup making, is not only a far better yielder than any of the others, but also is the least liable to lodge. It is therefore recommended as especially worthy of trial.

Sorghum is usually planted in rows and cultivated like corn. For ensilage purposes cowpeas may be planted with it to advantage. From 6 to 8 pounds of sorghum seed per acre are ample for forage and about 4 pounds for syrup. A good mixture for broadcast seeding is 1¼ bushel of peas and ¾ bushel of sorghum. If sown in rows, ½ bushel of peas is ample.

The same kind of fertilizers recommended for corn may be used for sorghum.

When planted in rows, sorghum may be put into the silo with the best of results; otherwise it is cut and shocked before frost and will make excellent feed up to about New Year's.

CROP ROTATION

A proper rotation, or change of crops, has much to do with soil fertility. In the most prosperous and longest organized farm communities definite crop rotations are followed year after year with little variation. The kind of crops grown must of course be suitable to the

climate, the soil, and the market conditions, but there are certain essentials to be kept in mind.

1. Leguminous crops are necessary to increase the soil supply of nitrogen. For this purpose cowpeas are the most easily grown, but in order to be of most benefit to the soil the crop must be either pastured off or turned under. Soy beans resemble cowpeas as soil improvers, but neither is equal to either crimson or red clover, with which alsike may be included. The clovers should be especially sought, for once the conditions for their satisfactory growth have been gotten, the solution of the soil fertility problem is not difficult.

2. There should be one or more cultivated crops so that weeds may be kept in check or eradicated. Good crops for this purpose are cowpeas or soy beans planted in rows, sorghum, tobacco, corn and cotton.

3. To put vegetable matter into the soil and increase its water-holding capacity, a grass crop is very important.

Generally speaking a long rotation, covering a period of five or more years, is better than a short two-or-three-year rotation. The following are given as examples of practical rotations, which have been tried at this Station:

LIST OF ROTATIONS

FIVE-YEAR LIVE STOCK ROTATION

1st year—Soy beans or cowpeas
2d year—Wheat
3d year—Clover and grass
4th year—Clover and grass
5th year—Corn, followed by winter cover crop for pasture and green manure

FIVE-YEAR GENERAL FARM ROTATION

1st year—Soy beans or cowpeas
2d year—Wheat
3d year—Clover
4th year—Cotton, followed by cover crop
5th year—Corn, followed by cover crop

THREE-YEAR COTTON PLANTER'S ROTATION

1st year—Oats, cowpeas, cover crop
2d year—Cotton
3d year—Corn and cowpeas

FOUR-YEAR COTTON PLANTER'S ROTATION

1st year—Cotton, followed by cover crop
2d year—Corn and cowpeas
3d year—Oats and Japan clover
4th year—Japan clover

GUIDE IN THE ESTABLISHMENT OF A ROTATION

The writer has prepared Table VI with the view of furnishing a practical guide during the establishment of the five-year general farming rotation. The spring of the year 1914 is taken as the commencement of the project and it is assumed that the land is in an ordinary state of fertility. According to this plan the rotation will not be in full operation until 1916; at least two years being required to accomplish this result.

It may be noted that after the establishment of the rotation—1916 and later—a change is made in the commercial fertilizers, both for corn and for the small-grain crop. This change consists in the omission of both the cottonseed meal and the muriate of potash. In the case of the rye, the manure would much more than replace these two ingredients and the residues from the clover and grass would be expected to furnish an appreciable supply of nitrogen for the corn which follows. Also in case of freshly cleared land neither meal nor potash salt is advised from the outset.

TABLE VI—*Five-year crop rotation showing crops, amount per acre of fertilizers, etc., suggested for each field during the establishment of the rotation, soil assumed to be in moderate need of phosphoric acid and poor in nitrogen—all operations assumed to begin in spring of* 1914

FIELD 1	FIELD 2	FIELD 3	FIELD 4	FIELD 5
1914 — Corn—followed with winter cover crop Acid phosphate 200 lbs., muriate of potash 20 lbs., cottonseed meal 100 lbs.	1914—Cowpeas Acid phosphate 200 lbs., muriate of potash 20 lbs.	1914—Soy beans Acid phosphate 200 lbs., muriate of potash 20 lbs.	1914—Spring oats Acid phosphate 200 lbs., muriate of potash 20 lbs., nitrate of soda 100 lbs.	1914—Spring oats Acid phosphate 200 lbs., muriate of potash 20 lbs., nitrate of soda 100 lbs.
1915—Soy beans Acid phosphate 200 lbs., muriate of potash 20 lbs.	1915—Wheat (sown in Oct., 1914) Ground limestone 2 tons, acid phosphate 200 lbs. in fall, manure 6-10 tons, top-dressed during the winter	1915—Corn — followed with winter cover crop Acid phosphate 200 lbs., muriate of potash 20 lbs., cottonseed meal 100 lbs.	1915—Red clover (sown late in Aug. or early in Sept., 1914) Ground limestone 2 tons, acid phosphate 300 lbs., muriate of potash 50 lbs.	1915—Clover and grass (sown late in Aug. or early in Sept., 1914) Ground limestone 2 tons, acid phosphate 300 lbs., muriate of potash 50 lbs.
1916—Wheat (sown in Oct., 1915) Ground limestone 2 tons, acid phosphate 200 lbs. in fall, manure 6-10 tons, top-dressed during the winter	1916—Clover and grass (sown in spring, 1915)	1916—Soy beans Acid phosphate 200 lbs., muriate of potash 20 lbs.	1916—Corn Acid phosphate 200 lbs., muriate of potash 20 lbs. Follow with winter cover crop	1916—Clover and grass (for hay and pasture)
1917—Clover and grass (sown in spring, 1916)	1917—Clover and grass (for hay and pasture)	1917—Wheat (sown in Oct., 1916) Ground limestone 2 tons, acid phosphate 200 lbs. in fall, manure 6-10 tons, top-dressed during the winter	1917—Soy beans Acid phosphate 200 lbs., muriate of potash 20 lbs.	1917—Corn — followed with winter cover Acid phosphate 200 lbs., muriate of potash 20 lbs.
1918—Clover and grass (for hay and pasture)	1918—Corn — followed with winter cover crop Acid phosphate 200 lbs., muriate of potash 20 lbs.	1918—Clover and grass (sown in spring, 1917)	1918—Wheat (sown in Oct., 1917) Acid phosphate 200 lbs., in fall, manure 6-10 tons, top-dressed during winter	1918—Soy beans Acid phosphate 200 lbs., muriate of potash 20 lbs.

NOTES ON TABLE VI

Liming

1. The liming may be done sooner than directed in the table. In fact, although especially beneficial to clover, liming is apt to increase the yield of any of the crops to an appreciable extent. According to our experimental evidence, two tons of ground limestone will be ample for at least five years, and possibly for twice that length of time.

Phosphate and potash

2. The acid phosphate and muriate of potash should always be applied before planting the crop for which they are especially intended, and give best results when applied in the row for crops planted in rows. For broadcast-sown crops these materials may be applied broadcast before the land is turned, or may either be drilled in afterward or scattered broadcast and well harrowed into the soil.

Cover crop

3. As a cover crop after corn, to prevent loss during the winter, choice may be had of wheat, rye, crimson clover, and hairy vetch. Crimson clover is an ideal crop in some respects, but requires a rather fertile soil in order to thrive. Even then, when sown in corn at the last working, it is apt to be killed before winter by dry, hot weather. Rye would help to hold the crimson clover from freezing out during the winter, and the mixture may be sown considerably later than crimson clover alone. Hairy vetch can be sown later than crimson clover and any time during September is favorable, provided the soil-moisture supply be good. If sown in early October it is apt to go through the winter. Like crimson clover it may be sown with either rye or wheat. Rye can be sown as late as wheat and makes the earliest spring growth.

When to turn cover crop

The cover crop should be turned under at a rather early stage of growth—in the case of rye and wheat not later than when in boot; but for crimson clover and vetch when in early bloom. Attention is called to the fact that vetch makes only a small growth during the fall, winter, and early spring, and is a vigorous grower only after warm weather comes in the spring; so that to get the most good out of this crop for green-manure purposes one must leave it on the land later by several weeks than either of the others, or until about the middle of May. This would not, however, be a serious objection, as either cowpeas or soy beans can be planted to advantage after this date.

Manure

4. The manure is advised as a top-dressing on the wheat for the special purpose of getting a good stand of clover and grass from a spring seeding. If the land is of such quality that the manure is not needed for this purpose it may well be applied for the corn crop, which offers a greater possible increase in grain than the wheat. In the absence

of manure an extra amount of both the phosphate and potash is advised.

Red or alsike clover

5. Either red or alsike clover may be used, and a mixture of the two is sometimes advisable. Alsike when sown in late summer or early fall would be expected to produce an appreciable part of the hay crop of the next two years, but red clover is apt to disappear after the first year. When spring-sown, one lasts about as long as the other, provided the red clover disease, which does not affect the alsike, is not serious.

Nitrate for grass

In the case of a failure of clover, in the spring following the seeding an application of 100 pounds per acre of nitrate of soda may be made to advantage for the grass, and should be applied as early in March as the spring growth begins.

Japan clover

In case of a poor stand of both clover and grass at the beginning of the second year a seeding of 25 pounds per acre of Japan clover (Lespedeza) about the first of April is recommended.

Velvet Beans

Agricultural Experiment Station

OF THE

University of Tennessee

BULLETIN No. 110 — OCTOBER, 1914

A SURVEY OF SHEEP AND LAMB PRODUCTION IN 1914

BY

R. M. MURPHY

KNOXVILLE, TENNESSEE

The Agricultural Experiment Station

OF THE UNIVERSITY OF TENNESSEE

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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

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A SURVEY OF SHEEP AND LAMB PRODUCTION IN 1914

BY

R. M. Murphy

INTRODUCTION

In 1909 this Station published a preliminary report on sheep and lambs in Tennessee (Bulletin 84). Up to April, 1914, no further investigation had been made of the subject. A careful survey of the same areas, namely, the sheep and lamb growing counties of Middle Tennessee, shows that practically the same system prevails now as is outlined in that report. The number of sheep and lambs increased markedly up to 1910, as shown by the Census report. The industry was comparatively new in that section. The possibility of the utilization of the grain fields as winter pasture for sheep had just dawned upon the farmers, and practically every one of them bought a flock of sheep and proceeded to join in the harvest of lambs the following spring. Since then there has been a steady decrease in the number of sheep kept. Many farmers who rushed into the business went out of it as hurriedly because they did not get results; and that, in most cases, was because they did not like sheep. The shortage this spring is more serious than the preceding year. This is due more to the severe drought of last summer than to any other one cause. Many who would otherwise have kept their flocks had to dispose of them because their pastures were burned up. Sheep are becoming scarcer every year in the rich lowland sections and increasing in number on the more rolling lands surrounding. As suggested in the former report, indications are that in the future the bulk of the lambs will come from the more mountainous sections of the State. Sheep do much better on high rolling lands. Stomach worms do not give nearly so much trouble on high lands. Formerly farmers

considered blue grass almost essential to sheep raising, but with the greatly increasing use of cereals in winter, together with crimson clover, orchard grass, and red clover in spring and summer, it has been found possible to produce sheep and lambs with a very small amount of blue grass. A great many lamb producers now allow their sheep to run on their blue grass lots very little, preferring to graze them with cattle and other live stock. This may mean that the farmer in the hill sections who does not have blue grass will be able to develop a system by which he can compete with his more favored neighbor in the production of spring lambs, since his lands are not nearly so high-priced and still may be made to furnish an abundance of pasture.

LOCATION AND EXTENT OF THE INDUSTRY

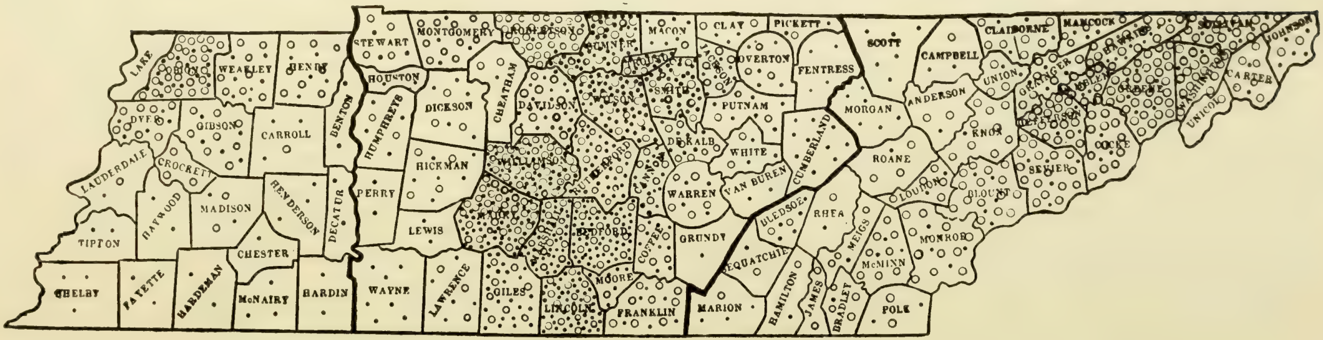
Practically every county in the State has a few sheep. The main industry, however, is confined to about eleven counties, within or bordering on the Middle Tennessee Basin. The flocks of this section have been drawn largely from the surrounding hill counties of the Highland Rim and the Cumberland Plateau, of this State, and from Northern Alabama and Mississippi. The former are commonly known as "mountain" ewes, and the latter as "Alabama" ewes.

While it is doubtless true that sheep came into this section in larger numbers than into any other part of the State, largely because it is the principal blue grass area of the State, and because it is contiguous to the Highland Rim and Northern Alabama, it is also very interesting to note the relation of the industry to the area devoted to wheat production. This area includes the largest wheat-growing section of the State. The sheep pasture on the grain fields from two to three months in the year, and, when the crop is not used for grain, as long as five months. This has been an important factor in the development of the sheep industry. The accompanying map shows how closely sheep raising and wheat growing are related.

This section has been supporting an average of two sheep per acre of wheat. Tennessee has a total wheat area of 619,861 acres, and two sheep for every acre would mean an increase of approximately 1,000,000 sheep, which would bring to the farmers of the State an increased income of $6,000,000 from sheep alone—and this with only three per cent of the farm lands sown to wheat.

A glance at the map shows that the counties of Sullivan, Washington, Hawkins, Hamblen, Grainger, Greene, Cocke, Jefferson, Sevier, Knox, Blount, Loudon, Monroe, and McMinn are not taking advantage of their opportunity, for they have practically as large a wheat acreage as the Middle Tennessee counties, with fewer sheep in the whole territory than either of the counties of Bedford or Wilson. The wheat fields of East Tennessee in their present state of fertility will

Map Showing the Distribution of Wheat Acreage and of Sheep in the State



○ = 1000 acres of wheat.
• = 1000 sheep.

not furnish as much pasturage as the average Middle Tennessee wheat field because the growth is not so rank. Bedford and Wilson Counties support four sheep per acre of wheat. One-half this number on the fields of East Tennessee would mean an increase of 400,000 sheep, or an annual additional income to the farmers of East Tennessee of approximately $2,000,000.

It is not probable that the wheat acreage will be very greatly increased, but each year there is a remarkable increase in the acreage of winter cover crops, which may be made to pay all costs of preparation and sowing by the pasturing of a few sheep upon them and still serve every purpose for which they were sown.

CAUSES OF INCREASE AND SUBSEQUENT DECLINE

The spring lamb industry in this State has developed largely within the last twenty years. The profits realized from a flock of sheep as a source of mutton and wool were not great enough to cause a general rush into the business before the spring lamb market developed. Sheep then became one of the most profitable kinds of live stock, considering the amount of investment and the ease with which they could be kept. When the farmer saw that he could buy a flock and allow them to run on his grass or meadow lots in summer and his grain fields in winter and realize a hundred per cent gross profit on his investment, he began to show a marked interest in the sheep business, and within a very few years practically every farmer in Middle Tennessee had a flock of sheep.

The practice of pasturing the grain fields during the winter months opened an entirely new avenue of profit and gave rise to the contention of sheepmen, still quite general, that their sheep do not cost them anything because they are kept principally upon the crops that had hitherto gone to waste. Such a contention is not entirely groundless so far as the grain fields are concerned, for when judiciously grazed they are not injured, and in some instances, where the tendency is to produce too rank a growth, they are benefited by pasturing. Sheep can be used more satisfactorily for this purpose than other live stock, due to the fact that the fields are often so wet and soft that heavier stock would injure them seriously by tramping. Of course where blue grass pastures are used the sheep should be charged with rental.

There has been a decline in the sheep industry, due to a number of causes, among which the gradual decrease in the number of stock ewes is most important. Investigation shows that not more than one per cent of the sheepmen keep up their flocks by reserving ewe lambs to replace those lost from various causes. The loss of ewes is about ten per cent per year.

The greatest losses of ewes occur at lambing time and from dogs. Considerable loss was reported the past year also from ewes in fat condition rolling on their backs, and, being unable to regain their feet, dying in that position. This occurs only in seasons of good pasturage.

The entire lamb crop is sold every year, and frequently when the ewes are in good enough flesh they go to market with the lambs. This spring fifty per cent of the ewes were sold with the lambs because of the unusually favorable season for grazing and the prevailing high price of mutton. It is fair to conclude that next year the crop will be much shorter than ever unless a new source of stock ewes can be found.

The yearly increasing price offered the "hill farmer" by the drover has tempted him to sell more and more closely until the "mountain" and the "Alabama" ewes are becoming very scarce. Naturally a great many farmers invested in sheep simply because their neighbors were making money out of them; but of these many did not continue long in the business, not finding it adapted to their system of management.

The recent high price of beef cattle has created a sentiment in favor of cattle as against sheep. Cattle do not graze well with sheep because the sheep clip the grass so close the cattle cannot get a bite.

The introduction and increase of parasites and diseases—stomach worm, scab, etc.—and the fear of depredation by dogs, have caused many farmers to lose interest in sheep raising.

KINDS OF SHEEP AND SOURCES OF SUPPLY

Up to the present time most of the stock ewes and what are known as "mountain" and "Alabama" ewes have come from the hill counties of this State and from Northern Alabama and Mississippi. As they exist today they are generally the first or second cross from the native type by a Southdown ram. Their popularity is due to their low cost, their prolificacy and their superiority as mothers.

Very few pure-bred flocks are to be found, and of these ninety-five per cent are Southdowns. There are a few Shropshires, Hampshires, Oxfords, and Dorsets, but they are not so popular as the Southdowns. Most of the flocks of pure-breds are maintained as a source of pure-bred rams. Pure-bred rams are used almost universally with a very strong preference for the Southdown.

Many Western ewes have been brought into different counties, but they have not given general satisfaction. They usually refuse to breed early enough the first year, since they have not ordinarily been bred so early, and they are necessarily shipped in too late to become well acclimated the first season. Another cause of their unpopularity

has been that scab was imported with them, which caused their purchasers much worry and expense. But inspection and dipping have been so rigidly enforced that this disease has been eliminated.

SYSTEM OF MANAGEMENT

There has not yet developed any system of maintaining the flock of ewes from year to year. The majority of sheepmen still follow the practice of disposing of the ewes with their lambs and buying back a new flock for the next year. Those who do not sell out their entire flock every year sell out every three or four years and start anew. Many follow the practice of keeping no sheep for a year now and then to allow their so-called "sheep-tired" pastures to rest. "Sheep-tired" is a very common expression, which to experienced sheepmen indicates that the pasture has become badly infested with stomach worms. Some breeders keep their flocks from year to year, each spring culling out the aged and barren ewes and replacing them by buying younger ones or by reserving enough ewe lambs to take their places.

Not infrequently the late ewe lambs are kept over, since there is no market for them, and if they escape the stomach worm the first summer they are put into the breeding flock. If not bred the first year they make very good ewes. When early lambs are reserved they are usually bred that same year. Very few breeders follow the practice of keeping good early lambs for breeding purposes, since they bring much more on the market than good stock ewes. Ewes are usually kept as long as they have "full mouths" (meaning that they have not lost any front teeth), if they do not become barren. In large flocks it is found just as profitable to keep ewes as long as they live, supplying about ten per cent each year to replace loss from various causes.

An old ewe which has reached this apparently useless age will rarely sell for more than $2.00 on the market, and yet when pastured during the winter on grain fields will not infrequently come up the next spring with a lamb worth from $5.00 to $6.00.

The ewes if purchased generally come on the market the latter part of June or first of July. Whether bought or kept over they receive much the same treatment in preparation for breeding season. When the lambs are sold the ewes are put on very short pasture or in a dry lot one or two days to decrease their milk flow, and those which have full udders are milked once or twice. They are kept in a short pasture until the last week in July so that they will be rather thin in flesh and will therefore breed earlier. This practice is not universal by any means, though it is conceded to give best results. Many sheepmen pay no attention to this matter, merely changing

from one pasture to another occasionally, and as a result they generally have lambs dropped from January to June.

Where the ewes are thin in flesh by the last week in July they are then placed on a fresh, rich pasture to "flush"* them. "Flushing" of ewes causes them to breed earlier.

The first of August the rams are put with the ewes—one ram to twenty-five ewes. Other things are suggested as means of bringing the ewes in heat earlier, such as driving them long distances, but these have not given general satisfaction. Ordinarily the rams are left with the flock until the ewes begin dropping lambs. They are then separated and are kept apart until the beginning of the next breeding season. Some breeders remove the rams by November 15, at the latest, so that no lambs will be dropped later than April 15. During the breeding season the flock has the run of the grain stubble fields and the clover fields in addition to the blue grass lots. They receive very little attention, other than salting twice a week, until lambing time.

Late in the fall or early winter they are turned on the grain fields, or fields of crimson clover and rye, sown especially for their use. This time varies with the season and the date the crop was sown. It is found best to keep them out of the grain fields until after they have dropped lambs. Each morning the ewes that have dropped lambs during the night are separated from the flock and placed in the grain fields. It is much safer to have the ewes lamb in a well-drained lot, such as a blue grass lot, than on the grain fields. The grain fields are often soft and wet at lambing season and there may be heavy loss of newly born lambs because they become wet and chilled.

Shelter is not considered practicable in this climate except in cases of small flocks of pure-bred sheep. It is too expensive to build a barn to use only two or three days, or at most, two weeks, during the year. If, however, there happen to be a cold, snowy, or rainy spell the loss is often heavy if no protection is available. Crowding the flock into the barn at lambing time always results in much trouble because of lambs getting lost from their mothers, especially in cases of ewes with twins. The first-born strays away before the other is up and when it returns the mother will not own it. A very good practice is to go through the flock each evening and separate the ewes that are heavy with lamb and shelter them for the night. On hillsides where cedars or other trees are plentiful the ewe always finds enough protection during an average winter. Care and attention are necessary and the man who reports a high percentage of

*The term "flush" means to bring about a vigorous condition by a short period of high feeding.

lambs is close by his flock at lambing time. Once the lamb is on its feet and has a little milk in its stomach it usually requires little more attention, but if it does not nurse soon after birth death quickly follows. Obstructions sometimes occur over the openings in the teats and the lambs fail to get nourishment. Ewes very thin in flesh frequently have no milk and refuse to own their lambs. If there are any motherless lambs in the flock there are usually enough ewes that have lost their lambs to take care of these. The ewe is hard to deceive and only through patience can she be made to accept a strange lamb.

While most breeders want their lambs dropped in January, there are only a few flocks where this is accomplished. Many of them are dropped from February to May, and some even later. As a result the early lambs become "staggy" or "bucky" before the later ones are ready for the market.

Castration is practiced by a few breeders. Some castrate only their January lambs. The later lambs go to market before they become "staggy."

MARKETING THE CROP

As before stated, many of the flocks are sold entire every year. This year fully fifty per cent of the flocks were disposed of at so much per ewe, ranging from $8.00 to $12.00, with the lambs thrown in. This was due to the fact that the ewes were unusually fat and the price of mutton was high. These ewes had cost on the average about $5.00.

The lamb market usually opens about June 1. This depends much upon the forwardness of the season and the resulting condition of the lambs. There is a limited demand for Easter lambs, at very attractive prices. Tennessee lambs topped the market in St. Louis this past year at 12 cents per pound. The lamb most desired for this market does not exceed 50 pounds in weight. This lamb if kept fifty days longer would have gained 50 pounds more, so that 8 cents per pound the first of June is quite as profitable as 12 cents the middle of April.

Most of the lambs are sold to shippers, who go through the country buying up the different lots at whatever price they can get them at. The lambs are purchased with the understanding that all lambs weighing 60 pounds or over shall be delivered at the shipping point on a certain date, those under 60 pounds to be delivered later. Competition among the buyers in different communities is so keen that the farmer usually gets a fair price for his lambs.

CLIPPING AND MARKETING WOOL

The flocks are clipped or shorn about May 1. Clipping machines are now used quite commonly and clip from 60 to 100 head per day. These machines are operated either by hand or by power. The average fleece of the native ewe weighs about 3 pounds and that of the high-grade and pure-bred ewe about 5 pounds.

The bulk of the wool is sold to local buyers soon after it is clipped. The buyers grade the wool and fix the price as it is brought in. The grade depends largely upon the presence or absence of burrs in the fleece. There are commonly three or four grades, as follows: Clear, slightly burred, burred, and hard or heavy burred. At the beginning of the season this past year the price offered was 20 cents per pound for clear wool and proportionately lower for the other grades, as low as 10 cents per pound being paid for fleeces grading hard burred. Later the price advanced to 23 cents per pound in a number of localities after the buyers had obtained all they could at 20 cents.

LAMB AND WOOL CLUBS

In a number of communities, such as Goodlettsville, Mt. Juliet, Martha, Baird's Mill and Bethany, the farmers have organized lamb and wool clubs, selling their products collectively to the highest bidder. After their wool is all clipped they decide upon a date for wool day and their secretary notifies buyers. When that day arrives the farmers bring in their wool, and it is graded and weighed by a committee of their own selection, from members of their clubs, and loaded into cars, which have been ordered previously. The bids of the buyers are then opened, and if they are satisfactory the highest bidder gets the entire lot. If not satisfactory the farmers ship it themselves. Each farmer is then paid in accordance with the weight and grade of his wool.

The prices received by the different clubs for their wool this past season are as follows:

Club	Grade No. 1		Grade No 2	
	Pounds	Cents	Pounds	Cents
Goodlettsville	7284	25.00	1034	21.00
Mt. Juliet	9000	24.13	900	21.00
Martha	....	24.60	....	22.10
Bethany	1800	23.87	80	21.50

The club at Goodlettsville has been organized for more than thirty years, and during that time the farmers in the club have never failed to get better prices than those outside. The clubs have established a reputation for carefully grading and tagging their wool and the buyers are glad to get it. As will be noted in the table, but slightly more than ten per cent of the wool grades No. 2, and there was no No. 3. At one of the clubs, a farmer brought a small quantity of No. 3, but he was asked to sell it somewhere else. The buyer can afford to pay them a better price, as he is sure of what he is getting.

The lambs belonging to these communities are handled in much the same way. Generally on wool day the secretary finds out from the different members the earliest date they can get a car load or a number of car loads ready for the market and each member agrees to deliver as many as he may care to that weigh over 60 pounds. The buyers are notified and are present as on wool day. They continue having these lamb days until their entire crop is sold. They have the advantage of much greater uniformity of lambs, since they have a much larger lot to pick from. They can utilize car space to much better advantage, and by having so many they get much stronger competition among the buyers.

Following is a facsimile of a card sent out by one of the lamb clubs:

Dear Sir:—

The ——— Wool and Lamb Club will sell wool May 21, 1914. Three Grades. First—Clear. Second—Slightly burred. Third—Heavy burred. All grades to be clear of tags. Bids close 1:30 P. M. day of sale.

First Lamb Day, Tuesday, June 9. Three grades. First—55 pounds and up, fat. Second—Over 50 pounds and medium flesh. Third—Culls, any weight. Bids close 1:30 day of sale.

Second Lamb Day, Tuesday, July 7. Three grades. First—60 pounds and up, fat. Second—50 to 60 pounds, fat. Third—Culls. Bids close 1:30 P. M. day of sale.

Right reserved to reject any or all bids.

————, Sec.

————,Tenn.

Telephone ————

————, Pres.

DOGS

Dogs continue to be a real menace to the sheep industry. The loss from this source is not very heavy, being only one-half of one per cent as a ten-year average, but the worry occasioned by dogs is much worse than the actual loss. The most common method of control now used is some form of poison, but this at best is very unsatisfactory, since there is no way of being sure whose dog will get it. The Dog Law in its present state is of no value whatever to the sheep grower.

NEEDS OF THE SHEEP INDUSTRY

The following suggestions are seemingly justified by conditions shown in the foregoing report. The most imperative need of the sheep industry is a supply of stock ewes. There would be no objection to the importing of these in the future as in the past if it were possible to obtain ewes of as satisfactory quality as formerly. The "Alabama" and "mountain" ewes are practically gone. Steps should be taken to prevent their complete extinction, for with the present outlook the "hill farmer" can make a good profit from breeding ewes alone. We shall never be able to get a substitute for them as cheap that will be one-half as satisfactory, especially as breeders and mothers.

Western ewes can doubtless be imported in the future with more general satisfaction than they have given in the past. More rigid inspection should prevent the bringing in of any more scab or other diseases. The greatest difficulty with Western ewes is going to be in getting them to breed earlier. Some Ohio sheepmen have followed very successfully the practice of buying Western ewes, bred before they are shipped. It may be possible to do the same thing here in Tennessee. They could be held over and bred to good rams and then be shipped into the State later than has been the custom. In the past there have been thousands of ewes disposed of every year in the West which have reached maturity but would ordinarily be good for two or more years in the South, and at the expiration of that time would sell as mutton for not much less than they originally cost. It is to be hoped that sometime in the future we may have a breed immune to the ravages of the stomach worm. The United States Government is at present conducting experiments with the different breeds in this connection, but no report has been made as to results. At present the Delaine seems to offer greater resistance to the stomach worm than any of the other breeds. It seems wise to suggest that this breed be given a trial. The fleece of the Delaine is much heavier and of much finer quality than that of the average Tennessee ewe, but its breeding qualities are not so good.

The wholesale disposal of ewes which has occurred this spring in many sections is very unfortunate. The majority of them are of satisfactory type, and just in their prime, and can not possibly be replaced for the price received for them. Everything indicates that next year sheep and lambs will be higher than ever before, and that the Tennessee lamb producer will have fewer lambs than he has had for years.

Selling the entire crop of lambs every year is a shortsighted policy. Even though the market offers as much as $8.00 for them it has not cost any more to produce them than the stock ewes will cost, and if they have been carefully selected from good mothers they are easily worth twice as much as the stock ewes that can be bought.

Every farmer should plan to maintain his own flock and each year it should improve. By selling off each year all ewes that have not proved satisfactory because of age, or type, or failure to breed or to raise a lamb, and replacing them with ewe lambs of good type from the best breeders and mothers, it is possible steadily to increase the productivity of the flock, granting, of course, that the proper care is exercised in the selection of rams. The general dissatisfaction with high-grade and pure-bred ewes as breeders seems to be due largely to the fact that they have been selected from the standpoint of type with little regard to anything else. It is not to be expected that we can improve the "mountain" ewe to the mutton conformation of the Southdown and still retain all her breeding powers. Originally, it must be remembered, her primary function was reproduction and the producing of either mutton or wool was of secondary importance. The highest development of either of these functions is very likely obtained at the expense of the others, so that in the development of ewes for future use it is highly important that selections be made with all of these things in mind. If selections be made from the standpoint of conformation alone a flock of poor breeders may be expected. The production of early lambs will likely continue to be, with us, the most profitable side of the industry. Hence, more attention should be given to type than to fleece; but in either case the breeding function must not be neglected. The continual improvement of the type increases the tendency to fatten easily so that much more attention is required if the flock is to be in proper flesh condition at the beginning of the breeding season. It is not to be denied that such a system will require greater care than where the flock is disposed of every year. Combating the stomach worm becomes a more serious problem where sheep are kept on the farm from year to year. The danger of importing diseases, however, is much less than where the practice is followed of buying a new flock every year.

Up to the present time the only means devised for controlling the stomach worm is a system of rotating pastures. The following

plan, suggested by Director H. A. Morgan, not only meets the demands of the sheep but embodies all the principles of a satisfactory rotation for Tennessee conditions. It cannot be hoped to exterminate the pest completely, but the infestation can be so well controlled that but slight loss should occur. Investigations indicate that an infested pasture if kept free of stock for one year becomes practically clean, and by plowing and cultivating, this cleansing may be accomplished in a much shorter time. This plan may be started at any season of the year, provided, of course, that the rotation has been gotten under way. Suppose we start at lambing time, January 1, placing each ewe as she lambs in the field of winter grain, such as wheat, barley, oats or rye, and there allow the flock to remain until March 15, when they must be removed to prevent injury to the grain yield. At this time they are turned on a field of crimson clover and rye, and later on the red clover field until the lambs go to market. When the lambs are sold the ewes are turned into the newly mown meadow, where the pasturage is very short, so that their milk flow will be diminished sufficiently to prevent the spoiling of their udders. Also this pasture helps to reduce their flesh condition preparatory to the breeding season. The last week in July they are put on a second-growth meadow or on some other rich pasture to "flush" them, and the first of August the rams are turned in with them. From then until the first of January they are allowed the run of the stubble of the grain and clover fields, in addition to blue grass, when they are again turned on the grain fields. This completes the circle, and has kept the flock on clean pasture all of the time. The following outline shows how the plan works out, using a five-year rotation in addition to a permanent meadow and blue grass lots:

Fields	1	2	3	4	5	6	7
1st year..	Barley	Clover	Clover	Corn Crimson clover and rye	Soy beans	Permanent meadow	Blue grass
2nd year .	Clover	Clover	Corn Crimson clover and rye	Soy beans	Barley	"	"
3rd year..	Clover	Corn	Soy beans	Barley	Clover	"	"
4th year..	Corn Crimson clover and rye	Soy beans	Barley	Clover	Clover	"	"
5th year..	Soy beans	Barley	Clover	Clover	Corn Crimson clover and rye	"	"

In the above plan barley is used as the winter grain crop and the corn crop is followed each winter with a cover crop of rye and crimson clover.

Next to the stomach worm, the most difficult thing to control is the time of breeding. This perhaps can never be controlled perfectly, but it is greatly influenced by the flesh condition of the ewes at the beginning of the breeding season. The ewe that reaches breeding season in an over-fat condition will not breed early and can not be expected to breed until the nights become cool. This can be accomplished by the selection year after year of ewes that breed early, the late breeders being disposed of.

It is just as important that the rams be in a thrifty, not over-fat condition. This matter of early breeding is very important from the standpoint of profit and of control of the stomach worm. If the lambs are handled properly the January lambs will weigh 20 pounds more than the later ones, which makes a marked difference at selling time. The later lambs grow so much more rapidly than the early lambs, owing to more favorable weather and better grass, that so far as the market is concerned they are just as satisfactory, or even more so; but they do not have the weight at selling time. It is true that the early lamb is often discriminated against on the market, owing to his "staggy" appearance, but this should be controlled by castration. The same trouble was experienced by the Wisconsin lamb growers until castration became a general practice with them. The rams should be separated from the flock by November 1, so that no lambs will be dropped later than the first of April.

The wool crop is likely to continue secondary in importance to the lamb crop of the State. It is of sufficient importance, however, to deserve more care in tagging and tying than it now commonly receives. A little attention to this matter would increase the price from 3 to 5 cents per pound, as shown by the experience of the lamb clubs.

The wool and lamb clubs have accomplished much in the communities where they have been organized. They may all be considered successful so far as they have gone, but their success has depended too much on a few individuals. The organizations are too loose. The average farmer does not feel himself under any special obligation to make the club a success. Members should not be allowed to sell outside of the club. A member who sells outside not only loses more often than he gains, but he hurts every other member. The clubs have already accomplished much in improving their wool crop. There is a great field ahead of them for rapid improvement of flocks in every respect. With stronger organizations they can buy rams of uniform type and breeding and all the flocks of a community may attain the uniformity of any single flock in the community. They can accomplish much more together than individually because they are working with much greater numbers.

The dog continues to be a very serious handicap to the sheep industry. The average loss of one-half of one per cent in ten years, as given in the above report, is slight, but a single invasion in the course of ten years lingers long in the memories of all concerned. A great many people will not raise sheep for fear of dogs. And individuals in communities where there are no sheep can hardly afford to take the risk. An increase in the number of sheep must come largely through united community effort. Wherever a whole community engages in sheep raising there is sufficient sentiment against the dogs to control them, whereas the individual would be helpless. Dogs can best be controlled by a tax, which is held in the county treasury to pay for all damages caused by them. Then, even if the farmer does lose a few sheep he gets paid market value for them, and furthermore the great majority of the worthless curs will be disposed of. Appended is an outline of a suggested dog law, which, if put into effect, would give the sheep industry of the State better conditions than now obtain. This outline was prepared by the Bureau of Animal Industry of the United States Department of Agriculture.

APPENDIX

Outline of a Suggested State Law, Combining Parts of Various State Laws, with Some Added Features Calculated to Give Sheep Owners the Benefit in Cases Where Proof of Facts is Difficult

Taxation of Dogs.

1. State to license and tax all dogs six months of age or over, which are not licensed and taxed by cities or incorporated villages.

2. All licensed dogs to be taxed as follows:

One male	$1.50
Each additional male	3.00
One female	3.00
Each additional female	5.00

Kennel licenses to be issued with restrictions (see Kennel License Law of State of Connecticut).

3. Counties or townships should be empowered to levy additional taxes on dogs should it be deemed necessary.

Issuing license, payment of tax, and identification of dogs.

1. All dogs six months of age or over to be reported by owner to proper county official for licensing. Owner shall also be responsible for relicensing dogs at end of year.

2. All taxes to be paid by owner to proper county official at time of licensing.

3. All dogs to wear collar showing owner's name and having attached a metal plate bearing license number and date and place of issue of license.

Handling of sheep-killing dog.

1. Dog may be killed by anyone—
   (a) When caught chasing or killing a sheep.
   (b) When caught off owner's premises, unattended and without a collar bearing license number.

2. A reward of $15.00 to be offered by proper county official to anyone identifying sheep-killing dog. (Money for payment of reward to be taken from funds accumulating from dog taxes).

3. Dogs must be ordered killed by authorized official when proved to be sheep killers.

Compensation to sheep owner for sheep injured or killed.

1. Authorized county official to pay owners of sheep injured or killed, the full value of damage done, from the funds accumulating from dog taxes. Should such funds be insufficient to pay all damages in full, other funds to be made available for this purpose. But should such funds accumulate in excess of amount required to pay damages, the same to be made available for some public service after three years' time.

2. Counties should have power to proceed against dog owners to regain all money paid out for injuries to sheep.

Agricultural Experiment Station

OF THE

University of Tennessee

BULLETIN NO. 111 (Technical Series No. 4) JANUARY, 1915

TWO EQUIPMENTS FOR INVESTIGATION OF SOIL LEACHINGS

A PIT EQUIPMENT

BY

C. A. MOOERS

A HILLSIDE EQIUPMENT

BY

W. H. MACINTIRE

KNOXVILLE, TENNESSEE

The Agricultural Experiment Station

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A PIT EQUIPMENT FOR INVESTIGATION OF SOIL LEACHINGS

BY

C. A. MOOERS

A cement pit, surrounded by thirty-four drainage cans for soil investigation work at the Tennessee Experiment Station, was completed in the fall of 1911. This plant differs materially in design from any other with which the writer is acquainted, and may therefore be of interest to other investigators.

The plant is located on a terrace, which is of advantage in the disposal of the waste water. A general view of the exterior is shown in Plate 1, and of the interior in Plate 2. The inside dimensions of the pit are as follows:

Length	81.5 ft.
Width	5.3 "
Height	6.5 "

The walls are made of reinforced concrete, 9 inches thick at the base and 5 inches at the top. The roof, which is arched and of like construction to the walls, is 4 inches thick, and contains four windows, each 2 feet square. These, together with a 2-ft.-square glass in the door at one end of the pit, furnish ample light. The cement floor was constructed with a slight grade, so that a trough about 5 inches deep, which runs the length of the pit and empties into a tile from the outside, easily carries the water discarded from the containers.

Round openings about 4 inches in diameter were left in the walls for the block tin tubes. The large size of the openings facilitates the work of adjusting the cans to the proper level at the time of setting, and also of making any later change which may be necessary. After the cans were set these openings were closed with cement on the inside of the pit, and the pipes are held securely at the proper levels. Since block tin does not endure being sharply bent, provision was made for removing the water from the containers without disturbing the tubes. This was accomplished in the case of the eighteen containers for the shallow cans and the rain gauges by drawing off the water by means of large faucets, which were high enough from the floor to allow a low-wheeled carriage, holding the scales and a weighing can, to pass freely under. The eighteen deep cans had outlets so near the floor that it was necessary to move the containers in order to empty them. In this case each drainage tube passed lightly through a cork stopper, about 1¼ inch in diameter, set in a thimble, to a raised cover about 6 inches in diameter. This cover can be easily pushed up on the outlet tube, where it holds itself in place. The container can then be withdrawn without coming into contact with the tube, and the opening

for the cover serves as a discharge opening for the water.

In the two winters that have passed since the construction of the pit, the water in the containers has not frozen, although near-zero weather has occurred. In the summer, of course, the air in the pit is of appreciably lower temperature than that on the outside.

Sunk in the ground about the pit are thirty-four heavy galvanized iron cans and two rain gauges, one at each end of the pit. Each can and rain gauge is 1-5000 acre in surface area. The cans are of four different depths. One set of eight are 1 foot deep, and hold 9 inches of soil, another set of eight are 2 feet deep; a third set, of fourteen cans, are 4 feet deep; and a fourth set, of four cans, are 6 feet deep. Every can is provided with a block tin outlet, which passes through and is cemented in the pit wall, and empties into a receiver as outlined. The cans are made of No. 14 galvanized iron, and each has a strong iron band, ¼ in. x 1 in., at the top to give stability.

The containers for the drainage water are of galvanized iron, but are well paraffined on the inside. Each container holds nearly 200 pounds of water, and has proved of adequate size. Before the cans were filled, a strainer, consisting of a small wad of glass wool, was placed over the block tin outlet tube, and about one inch of clean river sand was placed in the bottom of each can to facilitate drainage.

Three distinct types of soil, each of prominent occurrence in the State, have been used in the experiments. One type fills four cans of each of the different depths; that is, four 1-ft., four 2-ft., four 4-ft., and four 6-ft. cans. Another type fills four 1-ft., four 2-ft., and six 4-ft. cans. The third type occupies only four 4-ft. cans. Each kind of soil was removed from the field in layers, and each layer, after being carefully mixed, was laid down in the same order in the can as it was removed from the field. The 6-ft. cans, for example, were filled as follows:

First 2 feet at the bottom with subsoil from 4- to 6-ft. depths; the next 2 feet with the 2- to 4-ft. layer as found in the field; the 1- to 2-ft. layer represents the subsoil between these two depths in the field; the 6- to 12-in. layer represents the subsoil between these depths; and finally there is the surface layer, or plowed part of the soil. The various layers were weighed out and tamped down in as uniform a manner as possible by hand. The whole plant is covered with a ½-inch-mesh wire cage, but is otherwise fully exposed to the weather.

Complete data are not at hand as to the cost of installation of the plant, because farm help was used in connection with the excavation—which in this case was not an important item—also in the setting and loading of the cans. The major items, however, are as follows:

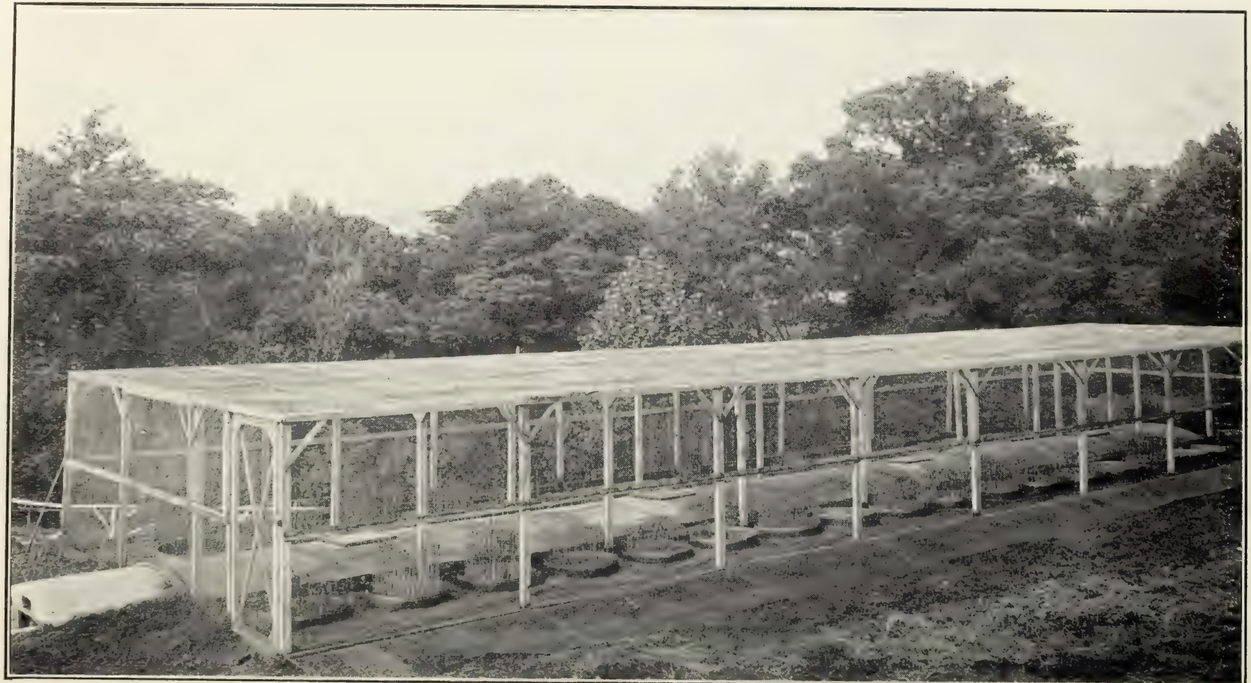

Plate 1, General View of Pit System

Plate 2, Interior View of Pit Showing Two Forms of Containers Used

Construction of pit	$ 453.00
34 Drainage cans	500.00
2 Rain gauges	25.00
36 Containers for drainage water	120.00
Labor of plumbers	10.00
4700 sq. ft. ½-in.-mesh wire cloth	131.00
Other materials, and labor in construction of cage	75.00
Block tin tubing	13.50
Benches for containers	15.00
	$1342.50

The cans being of different depths permits data being obtained in regard to the amount of water which passes through the soil at each depth, and it is proposed to carry out the experiments under both cropped and uncropped conditions. Also data will be obtained on the yield of the crops as influenced by the different depths of subsoil. One of the main objects, however, is to determine the amount and form of nitrogen which is leached out under the various conditions, such as depth of soil, kind of soil and manurial treatment. The present plan includes the growing of non-legumes, two crops each year, for the first two years (which has now been done), to let the cans remain uncropped for the next two years, and then to grow legumes for two years. All of the crops are analyzed for nitrogen. Composite samples of the drainage water from each can are saved for mineral analysis at the end of each year. The soils were of course carefully analyzed at the outset, and analyses are made of the manure used. The manurial treatments per set of four cans are as follows:

1. Lime
2. Manure
3. Lime and manure
4. No treatment

A HILLSIDE EQUIPMENT FOR INVESTIGATION OF SOIL LEACHINGS

BY

W. H. MacIntire

CONCRETE STRUCTURE

The terraced hillside drainage plant for soil investigations shown in Plates 3 and 4 was constructed in July, 1914. The system differs somewhat from the pit type; the embedded soil tanks extend in a straight line and one side of the subway for collecting drainage is open. The structure is based upon a 6-ft. perpendicular concrete wall built against the side of a terrace. The top of the terrace, in which the soil tanks are sunk, is flush with the top of the retaining wall, and is about 6 feet wide. The wall is 100 feet long, not including the portion serving as a brace to the steps which lead from the top of the terrace to its base, where the drainage is collected. At its base the wall is 9 inches thick, grading to 6 inches at the top. During the building of the wall, 3-inch tin pipe was placed in the concrete, at right angles to the face of the wall, in order to furnish openings to permit the passage of block tin tubing from the tanks sunk in the ground above to the drainage reservoirs located in the subway. At the base of the wall and parallel with it, a floor 6 inches thick and 6 feet wide was laid. This floor contains a trough in the center, and a gentle slope was given from the steps at the upper end to the lower end, in order that the waste water might be drained and discharged through an opening in the retaining wall at the lower end. The floor is covered by a roof, extending from the top of the wall to a supporting row of 4 x 4 posts parallel to the long wall and set along the outside edge of the floor. The frame of the roof was constructed of 2 x 4 lumber and anchored to the row of 4 x 4 posts supporting the frame for the wire enclosure for the space where the tanks were sunk. The roof was made of No. 2 common tongue-and-grooved flooring and covered with "ruberoid" roofing. The steps leading from the top of the terrace to the floor serve as a retaining wall and as protection from weather at the upper end of the plant, while a 6-inch retaining wall, 6 feet in length and 6 feet high, and at right angles to the long wall, serves the same purpose at the lower end. The walls were built with a mixture of 1 of cement, 2½ of sand, and 5 of pea-sized gravel. The lower 4 inches of the floor were made of the same mixture, while the upper 2 inches were finished with proportions of 1, 1½ and 2. A "brush finish" was given the entire exposed surface of the concrete walls.

CONTAINERS FOR TREATED SOILS

The tanks used for containing the treated soils were made of

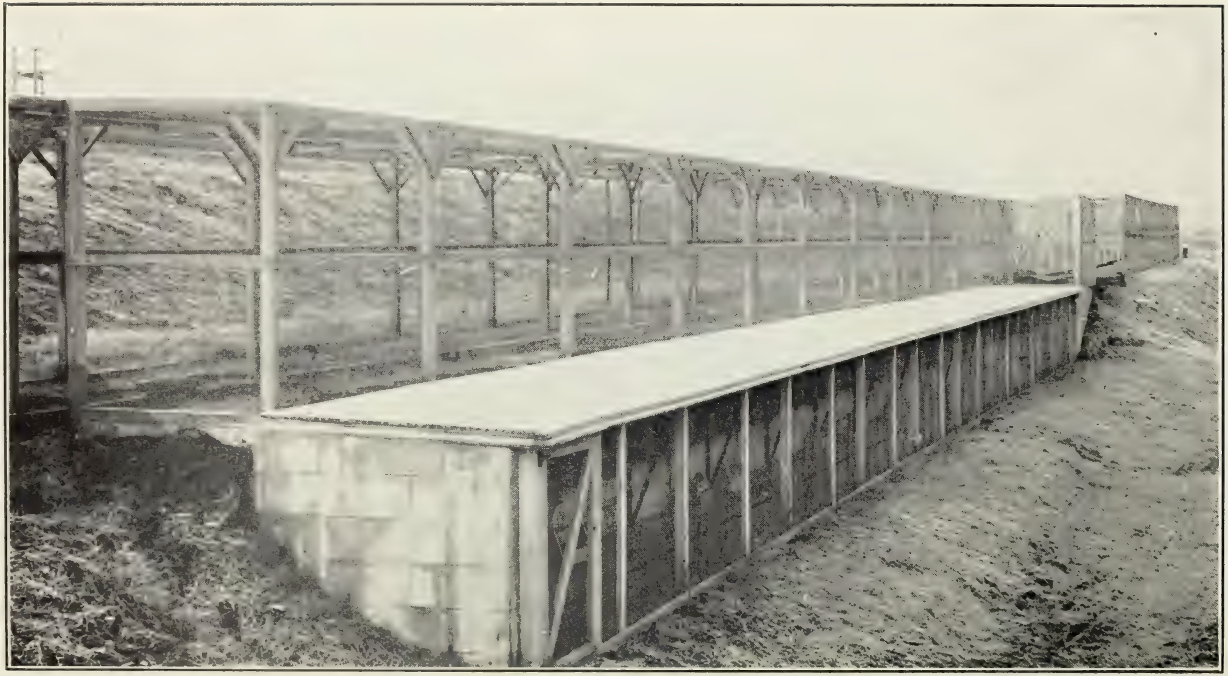

Plate 3, General View of Hillside System

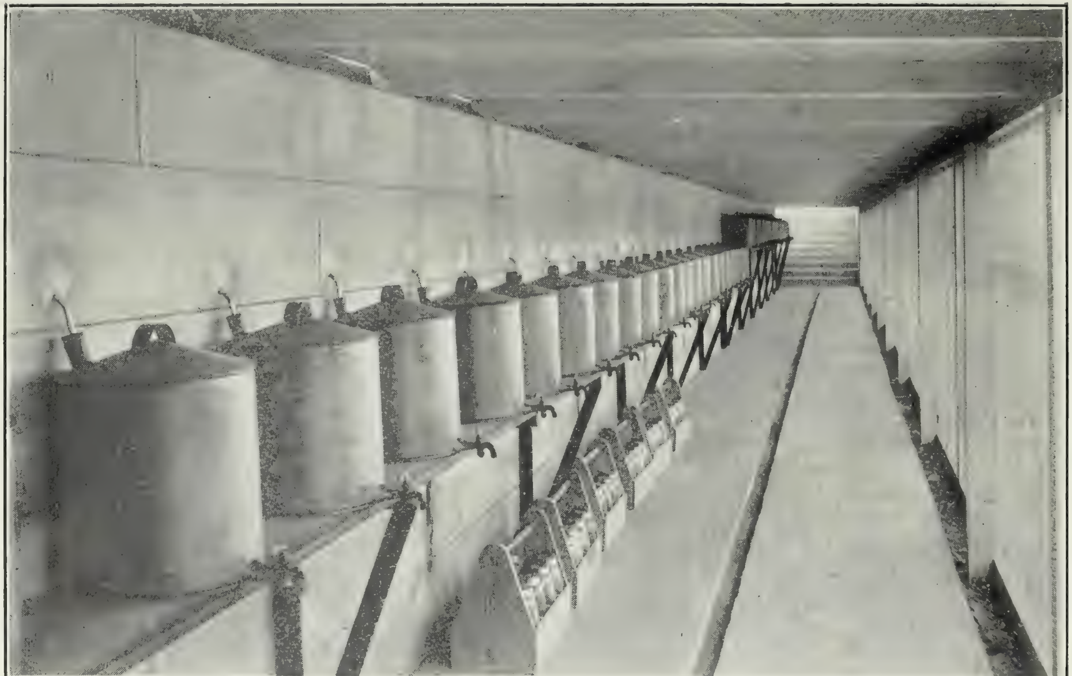

Plate 4, Interior View of Hillside System

14-gage galvanized ingot iron, strengthened at the top by means of a 3-16 x 3-4 in. wrought-iron band. Each container embraces an area of 1-20,000 of an acre. The outer circumferences of the tanks were placed 5 inches from the inner face of the wall. The outlets for delivery of the drainage were secured by the drilling of holes in the tanks just at the union of side and bottom, and the insertion and flanging of a ½-inch block tin tube, which was then soldered before the tanks were placed. The tanks were painted inside and out with black asphaltum paint.

The system contains two sets of tanks; the first set of twenty-one being 12 inches in depth, and the second set of twenty-three being 24 inches in depth. The tanks of the first and second sets are embedded 8 and 20 inches, respectively, in the ground. One inch of a 2-mm-sieved river-bottom sand was placed in each tank before the treated soil was introduced. The sand was prevented from washing into the drainage tubes by pads of glass wool. The whole plant is protected from interference by a ¼-inch-mesh wire cloth enclosure.

CONTAINERS FOR COLLECTING LEACHINGS

The ends of the block tin drainage delivery tubes are beveled and pass through corks, which fit into raised necks in the convex tight-fitting lids of the cans used to catch leachings. The cans were made of 20-gage galvanized iron, and are of 7½ gallons capacity. They are painted inside and out with black asphaltum paint, except the brass spigot for drawing off the water. The insides of the cans were further treated by the application of a thin coat of hot paraffin. The cans receiving the drainage waters rest upon 14-inch board shelves, which are supported by wooden braces, extending to the floor. The shelves are attached to iron shelf brackets, by means of which the shelving is anchored to wooden strips sunk at 8-foot intervals in the perpendicular concrete wall. The drainage waters run into containers on the platform of scales resting upon a carriage, and are weighed. Two-quart jars are used to convey portions of the water to the laboratory for analysis.

SOIL TREATMENTS

The twenty-one tanks of the first set contain only surface soil, which rests directly on the sand filter bed. In the first twenty-one tanks of the second set of twenty-three the surface-soil treatments constitute a duplication of the treatments of the first set; but in the second set 1 foot of clay subsoil was placed upon the sand filter before addition of the treated surface-soil. Several days were allowed for the tanks to settle after the treated soil was added and before the block tin tubes were sealed in the openings of the concrete wall.

One hundred pounds of moisture-free surface loam soil, representing a depth of approximately 8 inches, was used for each tank. The soil used for treatments was thoroughly screened through a ¼-inch sieve, carefully mixed, and closely covered during the overnight period required for the making of moisture determinations, and during the

mixing of soil and materials. The soil and treatment of each tank were thoroughly mixed in metal-lined boxes before being placed.

The plan of the experiment calls for a study of the activities of various forms of lime and magnesia. The scheme involves a study of the activities between the soil and the various materials applied, and the analyses of drainage waters are to be supplemented by periodic chemical examination of the residual materials. The plans of the project call for exclusion of all plant growth from the soils. Future analytical work may, however, make it appear advisable to introduce this factor.

COST OF THE SYSTEM

The installation cost of the system is given in detail in the following estimate. All costs are included except salaries of scientific men assisting in installing the system and making the various treatments before placing the soil:

Concrete walls, steps and floor	$252.47
Lumber for enclosures and roof	49.75
Gravel, plus freight and hauling of same	30.00
Grading	30.00
Wire cloth for screening	86.72
44 soil tanks and 44 cans for leachings	289.55
Roofing material	18.00
Carpenter work	20.00
Block tin tubing	7.50
Painting	16.00
Labor in placing cans and obtaining soil	12.00
Hardware incidentals	3.50
	$815.49

FEATURES OF THE HILLSIDE SYSTEM

The terrace drainage system shown is so arranged that no direct sunshine can reach the containers for the accumulating drainage waters. The cans used to collect drainage rest upon shelves and are close to the wall, where a fairly low temperature is maintained. The subway, though open on one side, is amply protected from inclement weather because of its location against the terrace, and the soil tanks are exposed to natural weather conditions in the same manner as in the pit system. We do not anticipate any weather conditions which will make the operation of the plant to any extent infeasible. In colder climates the cans might be protected by felt jackets.

The system lends itself to educational purposes, since the entire plant can be plainly seen by spectators without their entering the enclosures.

Because of the many mechanical difficulties to be met and overcome in the installation of such a system, the plant is described in detail and illustrated, with the hope that some benefit may be derived from our experience by investigators anticipating the inauguration of such methods of soil study.

Agricultural Experiment Station

OF THE

University of Tennessee

BULLETIN NO. 112 JANUARY, 1915

THE SMALL GRAINS IN TENNESSEE

By

C. A. MOOERS

SCENE ON UNIVERSITY FARM

KNOXVILLE, TENNESSEE

The Agricultural Experiment Station

OF THE UNIVERSITY OF TENNESSEE

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THE SMALL GRAINS IN TENNESSEE

WHEAT

At the present time wheat is the staple winter cereal of Tennessee, and is grown not only for grain but also for pasture. Wheat is preferred because it is a money crop which is easily disposed of, because of its certainty and its adaptability to the ordinary uplands, and also because of its fitness as a nurse crop for clover and grass.

VARIETIES

Within the last fifteen years more than sixty varieties have been tried by the Station. Throughout this period Fulcaster has been consistently a leading variety, and it is therefore taken as the standard of comparison in the tables. Table I gives a summary of the trials made from 1900 to 1904, inclusive, and Table II gives a summary of the trials made since that time. From these tables a list of the best varieties—those which came within 6 per cent of yielding as much in either series as Fulcaster—has been prepared, as follows:

Fulcaster
Kansas Mortgage Lifter
Deitz Longberry
Fultz
Valley
Improved Poole
Poole
Currell's Prolific
Red Russian
Harvest King
Red Prolific

Although any one of this select number can be regarded as a suitable variety for average Tennessee conditions, Kansas Mortgage Lifter and Fulcaster are the leaders, not only in yield, but also in quality of grain.

TABLE I—*Variety trials of wheat, 1900 to 1904, inclusive*

Average yield of Fulcaster for the five years, 35 bushels per acre

Fulcaster in comparison with—	Number of years tested	Number of years in favor of Fulcaster	Average yield per acre in favor of Fulcaster
			Bu.
American Bronze	4	3	7.0
Beardless Fulcaster	4	3	6.2
Blue Ridge	5	4	4.6
Blue Straw Fultz	5	5	6.5
Buck Woods Hybrid	5	4	6.8
California Red	4	2	3.2
Currell's Prolific	5	3	2.2
Dawson's Golden Chaff	4	3	9.6
Deitz Amber	5	3	0.2
Democrat	4	3	7.3
Diamond Grit	4	4	6.8
Early Pearl	5	5	11.2
Early Genesee Giant	5	5	8.1
Early Red Clawson	4	3	5.7
Early Ripe	5	3	6.2
Eclipse	4	4	12.0
Egyptian	5	4	3.2
Forty Fold	5	3	2.7
Fultz	5	3	0.1
Gold Coin	4	4	5.7
Harvest King	5	3	1.9
Hopper	4	3	5.2
Improved Fulcaster	4	3	—0.3
Improved Poole	4	2	1.0
Kansas Mortgage Lifter	5	2	—1.2
Lancaster	3	3	4.8
Mealey	5	5	5.2
Mediterranean	5	2	0.4
New Columbia	5	5	11.4
New Monarch	4	3	8.8
Niger	5	4	0.3
Perfection	5	3	3.0
Poole	5	4	0.8
Red Cross	4	3	4.8
Red May	5	3	4.1
Red Prolific	5	4	2.0
Red Russian	5	3	1.0
Rice	5	5	9.9
Rural New Yorker	5	3	3.4
Turkey Red	4	4	8.2
Valley	5	3	0.5
Velvet Chaff	5	3	5.6
White Golden Cross	4	4	4.7
White Winter No. 6	4	4	9.5
Winter King	4	4	9.7
4281	3	3	6.4
5342	3	3	8.6

TABLE II—*Variety trials of wheat, 1906 to 1914, inclusive**

Average yield of Fulcaster, 27.2 bushels per acre

Fulcaster in comparison with—	Number of years tested	Number of years in favor of Fulcaster	Average yield per acre in favor of Fulcaster
			Bu.
Abundance	2	2	12.1
Acme	4	1	1.2
Auburn	2	2	5.5
Blue Straw Fultz	2	2	6.9
Crimean	5	5	4.6
Currell's Prolific	4	2	2.2
Deitz Amber	3	3	4.2
Deitz Longberry	5	2	0.1
Early Genesee Giant	2	2	13.6
Early May	6	5	3.4
Fife	2	2	12.6
Fish Head	2	2	18.0
Fultz	5	3	0.8
Fultzo-Mediterranean	8	4	1.8
Iron Clad	2	2	2.3
Kansas Mortgage Lifter	2	1	0.5
Mediterranean	3	3	1.3
Niger	2	2	4.5
Onigara	5	4	5.7
Poole	9	6	0.9
Prosperity	3	3	12.0
Red Wonder	2	1	3.9
Swamp	5	5	7.4

*Thanks are due to the Office of Cereal Investigations, U. S. Department of Agriculture, for furnishing the seed of many of the varieties.

Of the beardless varieties Fultz and Poole are of special merit.

The Fultzo-Mediterranean variety is not included among the highest yielders, for on ordinary and even rich uplands a number of other varieties have surpassed it. It deserves special mention, however, because on extra rich land where the other varieties lodge it is apt to stand up, in which event it easily outyields them. Fultzo-Mediterranean grows appreciably shorter and produces a thicker and stronger straw than either Fulcaster or Poole. The head is beardless and compact, but the grain is of only fair quality. For some years it has been extensively grown in Maury County under the names of "Economy," "New Columbia," etc.

The Early May is another variety which is of interest. Like the Fultzo-Mediterranean, it is adapted to extra rich land because it is not apt to lodge. It is several days earlier than any of the other varieties, is beardless, and produces grain of extra quality, but in the Station trials has not yielded so well as Fultzo-Mediterranean.

IMPROVEMENT OF VARIETIES BY SELECTION

That many varieties of small grain and of other crops consist of a collection of well-defined or fixed strains, which may differ widely among themselves in productiveness, hardiness, etc., is now well known. Within recent years special attention has been given by agronomists to the improvement of certain crops through the selection of promising individuals, the seed of each individual being saved and grown separately so that the one best adapted to local conditions might be discovered. On the other hand, some varieties, especially those of recent origin or those which have been kept free from other varieties,

"BEST" POOLE

which are easily introduced in threshing, appear to be made up either of single strains or of strains so closely related that little improvement can be effected by selection.

EXPERIMENTAL RESULTS

Among the leading varieties of wheat mentioned on page 11, Poole was found by the writer to be especially susceptible of separation into distinct strains, a number of which were gotten in 1905 and 1906 and were afterwards included in the variety trials. Individual selections of Fulcaster were also used in the variety trials for several years.

Selections were made on an entirely different basis by Soule and Vanatter at this Station.* Their original plan included selections from each of two varieties of large, medium, and small heads and of a comparison, as a source of seed, of both large and small grains from the original varieties without regard to size of heads. This work was begun in 1900 and was continued by Soule and Vanatter until 1904. On taking charge of the agronomy work in 1905 the writer continued this study, using Poole and Fulcaster varieties and limiting the selections to those most apt to produce noticeable differences. The procedure, which was the same for each variety, was as follows:

1. A number of the largest heads were selected each year. These were hand-threshed, and the largest grains, separated by sieving, were used for seed. The first year, the selection was made from the general crop, but afterwards from the plot of the "Best", as this selection came to be known.

2. In a similar manner a selection was made of the smallest heads and the smallest grains, which were planted to themselves from year to year. These strains are called the "Poorest."

3. The original varieties were continued from year to year for comparison and are designated in the table as "Common" Poole and "Common" Fulcaster. The comparative yields of these selections in a five-year trial, from 1908 to 1912, inclusive, are given in Table III, which also contains the yields of two of the best pure strains from Poole.

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*Bul. Vol. XIV, No. 2 (1901).

TABLE III—*Yields of various selections of both Poole and Fulcaster wheat*

Variety	Selection	Year of harvest	Yield per acre	
			Grain	Straw
			Bu.	Ton
Poole	"Best"	1908	27.2	1.15
"	"	1909	31.0	1.75
"	"	1910	20.1	1.26
"	"	1911	19.0	0.82
"	"	1912	30.0	1.37
	Average		25.5	1.27
Poole	"Poorest"	1908	26.8	1.43
"	"	1909	25.1	1.94
"	"	1910	17.8	1.29
"	"	1911	14.8	0.73
"	"	1912	28.3	1.39
	Average		22.6	1.36
Poole	"Common"	1908	25.5	1.46
"	"	1909	29.6	1.82
"	"	1910	16.7	1.09
"	"	1911	14.7	0.66
"	"	1912	28.1	1.63
	Average		22.9	1.33
Poole	105	1908	27.5	1.27
"	"	1909	30.7	1.70
"	"	1910	19.1	1.30
"	'	1911	16.5	0.68
"	"	1912	32.5	1.50
	Average		25.3	1.29
Poole	134	1908	21.6	1.00
"	"	1909	32.4	2.02
"	"	1910	16.5	1.11
"	"	1911	15.5	0.69
"	"	1912	30.6	1.48
	Average		23.3	1.26

TABLE III—*Yields of various selections of both Poole and Fulcaster wheat (continued)*

Variety	Selection	Year of harvest	Yield per acre	
			Straw	Grain
			Bu.	Ton
Fulcaster	"Best"	1908	28.3	1.45
"	"	1909	22.7	1.49
"	"	1910	24.1	1.61
"	"	1911	18.1	0.94
"	"	1912	30.2	1.63
	Average		24.7	1.42
Fulcaster	"Poorest"	1908	29.1	1.47
"	"	1909	23.5	1.71
"	"	1910	22.2	1.45
"	"	1911	17.8	0.84
"	"	1912	28.3	1.59
	Average		24.2	1.41
Fulcaster	"Common"	1908	28.7	1.66
"	"	1909	23.5	1.70
"	"	1910	23.4	1.56
"	"	1911	16.2	0.82
"	"	1912	28.1	1.63
	Average		24.0	1.47

The results showed that Poole wheat could be separated into strains or varieties which had different yielding capacities. The continued selection of the largest and best heads resulted in a variety which yielded highest and was markedly different in general appearance from the variety obtained by selection of the most inferior heads. The heads of the former were uniformly long, rather "droopy," inclined to be pointed, and were dark green in color when immature. The heads of the latter were of medium size, straight, with a rather square top, and light green in color when immature. Among the pure strains one was found that resembled this selection very closely. Considering the extreme methods followed, the two sorts ran very close together in yield. Selection No. 105 had the general appearance of the "Best" but was more uniform in appearance, and grew slightly shorter than any of the others.

FULCASTER WHEAT, SHOWING TYPICAL LARGE, MEDIUM AND SMALL HEADS USED IN SEED SELECTION

The results with the Fulcaster variety show that no difference in yield was obtained by either method of seed selection. That is, the continued selection of the largest grains from the largest heads did not result in any special improvement, and the continued selection of the smallest grains from the smallest heads did not lower the yield. At the end of the experiments the two selections as seen growing in the field were practically identical in appearance. Also efforts to separate out strains by individual plant selections were without result. In short, the Fulcaster variety used in these experiments must have been a pure strain which was not capable of being changed by any of the methods used.

CHARACTERISTIC TYPES FOUND IN POOLE WHEAT

DATE OF SEEDING

The Hessian fly makes the early seeding of wheat hazardous. From the 10th to the 20th of October, when the first frosts are apt to occur, can be recommended for the latitude of Knoxville.

WINTER BARLEY

Winter barley has been grown for a number of years at the Station farm and has proved superior in several respects to other small grains. Barley makes the heaviest fall and winter pasture, matures the earliest in the spring, is the least liable to lodge of all the cereals,

and on rich land far outyields wheat, its nearest competitor. Also it is nearly as hardy and as sure a crop as wheat. Barley has, therefore, a distinct place in Tennessee agriculture, especially on the better class of soils and where improved methods of farming are followed.

VARIETIES

This Station has found only two varieties that proved to be strictly leaders. These are Tennessee, which has been grown in this State for many years, and Union, which was obtained from Canada about fifteen years ago. Both the varieties are bearded and are very much alike in general appearance, but Union grows shorter, is about three days earlier than Tennessee, and makes a somewhat quicker growth in the fall. They have been grown side by side for comparison for several years and Table IV gives the yields obtained.

TABLE IV—*Union versus Tennessee winter barley*

Crop of—	No. of plots averaged for each variety	Yield per acre			
		Union		Tennessee	
		Grain	Straw	Grain	Straw
		Bu.	Ton	Bu.	Ton
1906	3	53.8	1.76	52.5	2.23
1908	4	45.3	1.34	44.6	1.54
1910	5	34.0	1.20	32.9	1.54
1911	2	44.5	1.25	44.5	1.54
1912	1	27.6	0.69	30.2	0.88
	Average	41.0	1.25	40.9	1.55

The results of Table IV show very little difference between the two varieties in grain production, but indicate that Tennessee produces more straw than Union. In the date-of-seeding experiments, however, Union was found to excel Tennessee in the late seedings, in at least one instance, making a fair yield when Tennessee was a complete failure. This difference is seen in the following results, which give the average yield both of early and of late seedings of each variety in trials lasting six years:

	Yield of grain per acre	
	Tennessee	Union
	Bu.	Bu.
Average yield when sown between Sept. 9 and Oct. 7	44.8	45.1
Average yield when sown between Oct. 15 and Nov. 5	33.0	35.6

NEW WINTER BEARDLESS BARLEY

In addition to the two winter barleys mentioned, a third may now be included, and this is the new winter beardless barley originated at the Station by the crossing of Tennessee winter on a spring beardless barley. In the spring of 1909 several hundred crosses were made between these two barleys. Since then the number retained has been reduced to less than ten, and one of the most promising is now being distributed for trial throughout the State. The new barley has a head like that of common spring barley, but has apparently all of the hardiness of the Tennessee winter variety, and promises to yield equally as well as the latter. The name of the new barley is "Tennessee Experiment Station No. 50."

TENNESSEE EXPERIMENT STATION NO. 50

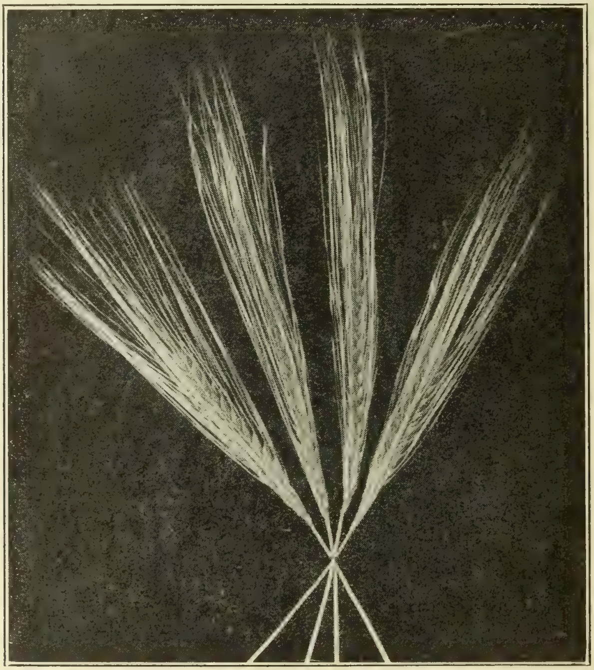
A winter beardless barley bred at the Station. A cross between Tennessee winter and a spring beardless barley

DATE OF SEEDING

Date-of-seeding experiments were conducted each year for six years with both Union and Tennessee varieties. The first seeding was made about the middle of September and a seeding was made every two weeks, as a rule, until early November. The results may be summarized for the six years as follows:

	Yield of grain per acre
Seedings from Sept. 17 to Sept. 29	50.9 Bu.
Seedings from Oct. 3 to Oct. 7	47.9 Bu.
Seedings from Oct. 14 to Oct. 19	38.2 Bu.

Seeding the latter half of September is, therefore, recommended as highly advisable. There was evidently a marked falling off in yield when seeding was done after the first week in October. These dates must of course be modified somewhat to suit other parts of the State.



TENNESSEE WINTER BARLEY

CLOVER AND BARLEY

Early September has proved to be an excellent time for the seeding of red clover, and since this is a favorable time for barley the two may be advantageously sown together. In fact, this has become the common practice at the Station farm, and the results have been so satisfactory that it is recommended for trial on the better class of soils. A light seeding of barley, say a bushel or a bushel and a half, favors the clover. In the absence of volunteer clover 12 pounds of red clover seed per acre or 8 pounds of alsike is advised.

SPRING BARLEY

Spring barley has proved to be inferior to spring oats and much less productive than winter barley. Spring barley may, however, be used as a nurse crop for a spring seeding of clover and grass, good stands of which are especially desired. This preference is given to spring barley as a nurse crop because it makes a quick early growth which is both short and thin but at the same time hinders the development of weeds.

CHARACTERISTIC VARIATIONS FOUND IN CULBERSON OATS
The short-strawed oat at the left shows the original of Tennessee Experiment Station No. 1

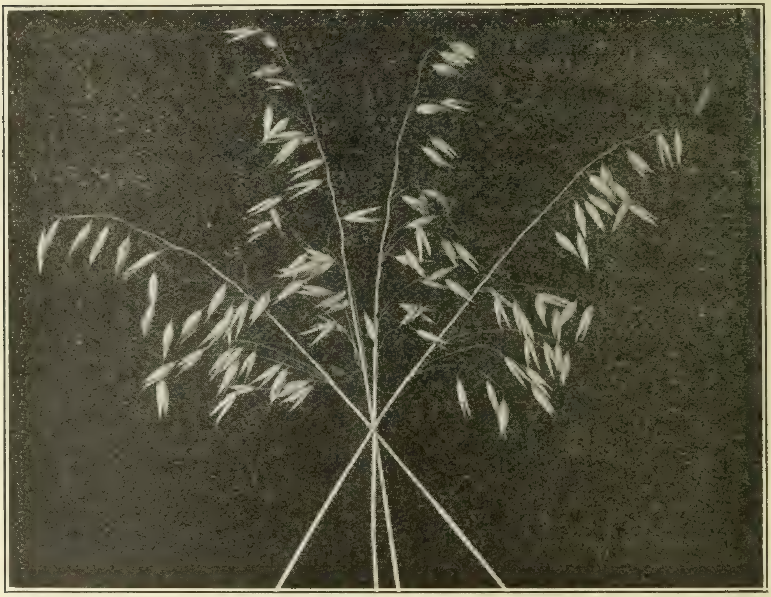
WINTER OATS

Winter oats are grown extensively in the Highland Rim section of Middle Tennessee and to some extent in other parts of the State. This crop is distinctly less hardy than either winter wheat or barley, suf-

fering more than either from both severe cold and attacks of insects. Winter oats are generally much more productive than spring oats and are recommended in preference to them whenever an early seeding can be made. At the Station farm, plant lice have done great damage to winter oats and are a most serious menace to the future development of the crop.

VARIETIES

In the states further south such varieties as Appler, Red Rust Proof and Fulgrum can be grown to advantage, but in this State they are uncertain, passing safely through some winters but not through others. The standard winter oat in this State is the Grey or Winter



TENNESSEE EXPERIMENT STATION NO. 1

Turf. This variety is uniform in type but is late in maturing and grows extra tall, producing a large amount of straw in proportion to grain. The Culberson winter oat, which appears to have come from Texas, has been grown here to a limited extent for a number of years. Seed was obtained by the Station about fifteen years ago, and the variety was soon found to be both early and hardy, but made up of a mixture of widely different strains, from which fixed strains were easily gotten by selection. One of the best of these selections is called "Tennessee Experiment Station No. 1." It matures about two weeks earlier than Winter Turf, is fully as good a grain producer, and has a shorter and stiffer straw, so that it is especially well suited to the better class of soils.

DATE OF SEEDING

Date-of-seeding experiments were made each year for five years. The first date was usually early in September and a seeding was planned to be made every two weeks until early November. Owing to variations in the season and the conditi ns of the ground regular dates were not found possible. The results obtained in the five years, however, may be summarized as follows:

	Yield of grain per acre
Seedings from Sept. 6 to Sept. 29	48.1 Bu.
Seedings from Oct. 1 to Oct. 19	40.5 Bu.
Seedings from Nov. 3 to Nov. 5	8.4 Bu.

September seeding has, therefore, given appreciably better results than were obtained the first half of October.

CLOVER AND OATS

Clover and oats may be sown together early in September to much advantage, the same as clover and barley. Culberson oats and clover mature together especially well and make an excellent mixture for hay.

SPRING OATS

Spring oats outyield spring barley (see Table VIII), but are inferior to winter oats, which, when planted at the proper season, far outyield them, as is shown in Table VII. Spring oats, however, are generally preferred after corn, which matures so late in the season and leaves the soil so dry as to make uncertain the successful seeding of the winter oat.

Burt oats have been used very successfully at the Station farm as a nurse crop for Kentucky blue grass when sown in the fall. The oats and grass seed are sown at the same time, the former binding the soil and protecting the grass, which is kept from freezing out during the winter. The oats are apt to be killed by midwinter but serve the purpose mentioned, and the grass has full chance to grow in the spring.

TABLE V—*Variety trials of spring oats—Burt versus Red Rust Proof*

Year	Yield per acre			
	Burt		Red Rust Proof	
	Grain	Straw	Grain	Straw
	Bu.	Ton	Bu.	Ton
1908	27.3	0.66	20.7	0.51
1909	20.2	0.54	23.3	0.67
1910	45.6	0.93	32.7	0.79
1911	14.9	0.37	12.8	0.31
1912	47.7	0.83	45.2	0.91
1913	22.5	0.43	10.7	0.30
Six-years av.	29.7	0.63	24.2	0.58

TABLE VI—*Variety trials of spring oats—Burt versus Kherson, or 60-Day Russian*

Year	Yield per acre			
	Burt		Kherson	
	Grain	Straw	Grain	Straw
	Bu.	Ton	Bu.	Ton
1906	31.8	0.71	26.7	1.00
1908	27.3	0.66	29.5	0.60
1909	20.2	0.54	26.4	0.71
1910	45.6	0.93	43.2	0.92
1911	14.9	0.37	12.6	0.29
1912	47.7	0.83	44.3	0.79
Six-years av.	31.3	0.67	30.5	0.72

TABLE VII—*Spring oats versus winter oats*

Year	Yield per acre					
	Spring oats				Winter oats	
	Red Rust Proof		Burt		Culberson	
	Grain	Straw	Grain	Straw	Grain	Straw
	Bu.	Ton	Bu.	Ton	Bu.	Ton
1902	47.2	1.39	61.3	1.02	68.0	1.69
1903	27.3	0.73	25.0	0.63	65.4	2.57
1911	12.8	0.31	14.9	0.37	21.1	0.59
1912	45.2	0.91	47.7	0.83	50.8	0.66
1913	10.7	0.30	22.5	0.43	35.9	0.56
1914	8.1	0.31	9.4	0.29	44.6	0.84
Average	25.2	0.66	30.1	0.60	47.6	1.15

TABLE VIII—*Spring oats versus spring barley*

Year	Yield per acre			
	Spring oats (Burt)		Spring barley (Beardless)	
	Grain	Straw	Grain	Straw
	Bu.	Ton	Bu.	Ton
1906	31.8	0.71	29.2	0.60
1907	35.1	0.86	14.1	0.61
1908	25.0	0.60	11.2	0.37
1909	20.2	0.54	9.8	0.51
Average	28.0	0.68	16.1	0.52
Pounds of grain per acre	896.0		772.8	

VARIETIES

The Burt oat has been the standard spring variety in Middle Tennessee for a number of years, and has now practically superseded all other varieties in the rest of the State. It is the earliest of all spring varieties, and to this fact must be attributed its chief advantage, for it will make a fair yield when the later kinds are cut down for lack of the one more rain necessary to their success. The difference between Burt and Red Rust Proof, which at one time was widely grown, is shown in Table V. The only rivals of the Burt that have been found by the Station are Kherson and Sixty-Day Russian. These two varieties are so similar that the writer can make no distinction between them. They mature only slightly later than Burt and have

Spring Oats in Experimental Plots

yielded nearly as well, as Table VI shows. None of these varieties can be used safely as winter oats, both Burt and Kherson being killed by only moderately cold weather.

DATE OF SEEDING

Spring oats should be sown early, but can be sown too early as well as too late. Date-of-seeding experiments to compare the yields from late February and early March seeding with the middle-of-March seeding have been made for five years. In four of the five years the yields have been in favor of the later date, but the difference has been small. The dates of the early plantings have varied from February 20 to March 4, and the average yield per acre was 25.6 bushels. The late plantings varied from March 12 to 17, and the average yield was 27.2 bushels. The larger yields which followed the middle-of-March seedings are attributed to the better stands which were obtained from those seedings.

TABLE IX—*Comparative yields of winter wheat, barley and oats*

Year of harvest	Kind of soil	Yield per acre					
		Winter wheat (Fulcaster)		Winter ~~oats~~ barley (Union)		Winter ~~barley~~ oats (Culberson, chiefly)	
		Grain	Straw	Grain	Straw	Grain	Straw
		Bu.	Ton	Bu.	Ton	Bu.	Ton
1906	Rich bottom land	30.7	1.82	54.8	1.75	49.8	2.11
1908	Rich bottom land	27.5	1.55	53.8	1.44	49.0	1.55
1910	Rich bottom land	24.7	1.92	36.5	1.28	27.8	0.56
1911	Fertile upland	18.1	0.94	44.4	1.25	21.1	0.59
1912	Fertile upland	28.9	1.62	28.9	0.79	50.8	0.66
1913	Fertile upland	25.0	1.78	37.0	0.95	35.9	0.56
1914	Fertile upland	26.1	1.22	44.6	1.51	44.6	0.84
	Average	25.9	1.55	42.9	1.28	39.9	0.98
Pounds of grain per acre		1554.0		2059.2		1276.8	

Table IX has been prepared to show the comparative yields from a seven-years trial of the three winter cereals, wheat, barley and oats. The results were obtained at the Experiment Station farm at Knoxville, on land that is considerably above the average in fertility. Barley easily came first, with 2059 pounds of grain per acre, on the average, wheat was next best, with 1554 pounds of grain per acre, on the average, and oats came last, with a yield of only 1279 pounds. Barley was not found, however, to lead in trials on very poor land, the results there being in favor of wheat, which is more hardy and a better forager under unfavorable conditions than barley.

WINTER RYE

Rye is an excellent winter cover crop both to prevent the loss of soil from rains and to furnish pasture and green feed for stock. For soiling purposes it is the earliest of the cereals. As a grain producer it has not proved on the Station farm to be equal to wheat. In a five-years trial the average yield of wheat was 1842 pounds, but of rye only 1299 pounds. The yield of straw was in favor of the rye, being 2.25 tons per acre as compared with 2.02 tons for the wheat.

No variety trials of sufficient value to be reported at this time have been made by the Station, but this is a matter worth further investigation.

The date of seeding of rye varies with the fertility of the soil and the objects in view. For pasture purposes it may well be sown in September and for grain about the middle of October, or the same as wheat. Rye can be sown successfully somewhat later than wheat, November seedings seldom being frozen out.

Agricultural Experiment Station
OF THE
University of Tennessee

BULLETIN NO. 113 — MARCH, 1915

THE NORTH AMERICAN FEVER TICK

(*Boophilus annulatus* Say)

NOTES ON LIFE-HISTORY

BY
E. C. COTTON

KNOXVILLE, TENNESSEE

The Agricultural Experiment Station

OF THE UNIVERSITY OF TENNESSEE

BROWN AYRES, President

The Experiment Station building, containing the offices and laboratories, and the plant house, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy building, etc., are located one mile west of the University on the Kingston Pike. The fruit farm is adjacent to the Industrial School, and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

THE NORTH AMERICAN FEVER TICK

(*Boophilus annulatus* Say)

By

E. C. Cotton

INTRODUCTORY

The original Federal quarantine line was established in 1892 as the northern limit of the area permanently infested with the Southern cattle fever, or, as it is more generally known, "Texas fever," as determined by field investigations[12]. The exact location of this line in any particular year depends very largely upon the severity or mildness of the preceding winter. In a rough way, as originally established, it followed the isotherm of 59° F. through the eastern part of the country and across the Mississippi Valley until the arid region of the Southwest was reached, where it bent sharply to the Mexican boundary. This boundary line was followed to southern California, where it turned northwestward, including within the quarantined territory a considerable area of the fertile valleys of the southern part of that State. North of this line was an area of considerable extent in which the ticks were killed off each winter and, through movement of infested cattle from south of the line, annually reinfested. Including this and extending much further north was an area subject to sporadic outbreaks of "splenetic fever" or "murrain". In this territory were included states as far north as New York, New Jersey, Pennsylvania, Ohio, Illinois, Kansas and even the Dakotas[11]. In nearly every case these outbreaks could be directly associated with Southern cattle introduced into the region or merely passing through. In every case sufficient time elapsed between the presence of the Southern cattle and the outbreak of the disease for the development of seed ticks from the eggs laid by engorged ticks dropping from the infested cattle. Numerous suggestions were offered by early investigators as to the manner in which infection is passed from one animal to another, and the matter was not finally cleared up until the epoch-making discovery of Drs. Smith and Kilborne was published in 1893[13]. Their work established on a scientific basis the direct relationship of the tick to the fever, proving beyond a question that the tick is necessary to the natural transmission of the disease from one animal to another. Of greater importance was the demonstration of the fact that the disease could be transmitted by seed ticks, developing from eggs laid by ticks engorged on blood from infected animals, attaching

to non-immune animals. It is now known that this blood parasite is imbibed with the blood of the host, migrating in some manner from the alimentary tract to the eggs produced by this female, finally reaching the salivary glands of the seed ticks developing therefrom. Upon attachment the seed tick injects into the blood of the host an anti-coagulin, secreted by the salivary gland[10], and with it the fever-producing organism. After an incubation period of about 13 days the host develops a fever due to the destruction, by the organism, of the red blood corpuscles, within which it multiplies by division, causing degeneration and disintegration of the corpuscles.

With the clear proof thus afforded of the intermediary function of the tick in the transmission of the fever from the sick animal to the well one came the recognition of the fact that this disease could be completely stamped out by the destruction of the tick, upon which it is absolutely dependent. In order that this might be done, more exact knowledge of the life-history and habits of the tick was demanded. Investigations of these subjects were already under way, having been undertaken by Dr. Cooper Curtice[3] at the Texas Station and by Prof. H. A. Morgan[7] at the Louisiana Station. These pioneers were followed by other investigators, until today we have a large amount of exact information, on which rational methods of eradication have been constructed. The control measures now in general use may be divided into two general classes: First, those in which the treatment is applied directly to the infested animals; and, second, those directed toward the cleaning of the pastures of the ticks, better known as the starvation method.

Under the first plan the cattle are allowed the full use of the infested pastures, from which they "pick up" the seed ticks. At regular intervals, which are always shorter than the time necessary for the development of the seed ticks to maturity, they are treated with a contact insecticide by spraying, dipping or hand-washing. In this manner most of the seed ticks would be picked up and brought to the dipping vat[1] or other place of treatment, and the remainder starved to death. As none of the ticks would be allowed to come to maturity, thus cutting off the source of reinfestation, one season should suffice for the complete eradication of the ticks from a given pasture.

The starvation method calls for the removal of the cattle from the pastures for a period equal to the total life-cycle of the tick. In other words, the cattle should be kept off the pasture until all of the seed ticks hatching from the eggs laid by the last tick that dropped off before the removal of the host from the pasture have starved to death.

The first plan is particularly applicable to the free-range districts of the tick area, while the second is better adapted to the more highly developed sections where a permanent agriculture has been established. In some localities a modified plan, or perhaps an adaptation of both methods, will yield the better results. Whatever method is adopted, that the tick can be completely eradicated from the whole South is clearly demonstrated by the annual shifting of the quarantine line further southward and the cleaning up of large areas far below the line. Concerted, consistent team work by all parties is required to accomplish this. Success invariably follows where such is given.

SOURCE OF MATERIAL

The inauguration and completion of this project was made possible through the kindly cooperation of the United States Bureau of Entomology Laboratory at Dallas, Texas, from which we received a total of 3665 engorged female ticks, sendings having been made at fairly regular intervals of a week or ten days, from August, 1906, to May, 1911. In addition to this supply a few ticks were secured as specimens sent in for identification by various individuals in Tennessee, most of whom were connected in some official capacity with the tick-eradication work. Most of these specimens were from Dr. W. P. Ellenberger, formerly in charge of the Federal quarantine work in this State. About 200 engorged females, selected from a lot reared to adult in the course of some experiments on the control of Texas fever, were also used.

Of these ticks the larger portion were used in experiments designed to determine the duration of the oviposition, incubation, and seed-tick stages of this species under outdoor conditions at Knoxville at all times of the year. Of the specimens so used 2315 were forwarded from Dallas.

For comparison with results secured under outdoor conditions, about 1000 engorged female ticks, their eggs, and the resulting seed ticks, were kept in the laboratory for the determination of the above-mentioned periods. The remainder were used for various purposes, particularly for the determination of the effect of high constant temperatures in the incubator, and for the study of the internal anatomy. Part of the results of the latter work are included in this bulletin.

The ticks forwarded from Dallas were collected from dairy cattle near that city and packed the same day in small tin boxes, with sufficient cotton linters or scraps of paper to prevent injury from the rough handling to which they were subjected in the mail sacks. They were usually two or three days in transit and even in midsummer very few of them had begun oviposition when they arrived. Occasionally a sending would be four to six days on the way, and in such cases, particularly when this occurred during the warmer part of the year, many, if not all, were laying when received. This fact did not necessarily vitiate the results, for in most instances a very close approximation to the time of beginning could be estimated from the number and condition of the eggs present. Whenever there was serious question as to the exact date of beginning, such date was not included in the records. Toward the latter part of the work the individual ticks in each sending were enclosed in gelatin (quinine) capsules and these, in turn, packed in the tin box as before. When the sendings were delayed in transit this method helped materially in determining which of the ticks were laying and how many eggs each had produced.

TECHNIC

Upon the arrival of the engorged ticks at the laboratory the usual practice was to place each individual in a separate pill box (about one and one-half inch in diameter), marking on the cover the experiment number and sub-

number. When egg-laying began, the date was entered on the cover, as was also the date on which the tick ceased laying. When all of the ticks in a given lot had ceased the eggs were transferred to bent-neck, or Comstock, bottles which had previously been prepared by filling about one-third full of clean, sterilized sand.

During part of the time covered by this work each sending was divided into two portions. One half of the ticks were kept in the laboratory and the other half immediately transferred to the wire house outdoors. Later, however, when it became clear that the results secured in the laboratory were not applicable to outdoor conditions, all of the ticks were placed outdoors, except such as were selected for special purposes. Whether the eggs and seed ticks were to be kept in the laboratory or outdoors, as soon as the oviposition of the adults had ended the eggs were divided into two nearly equal lots, one of which was placed on moist sand in a bent-neck bottle and the other on dry sand in a similar bottle, and both were kept under as nearly the same conditions otherwise as it was possible to secure.

As will be noticed by reference to Fig. 4, the mouth of each bottle was covered by a piece of muslin, fastened on by means of a rubber band. In the beginning considerable difficulty was experienced in supplying moisture to the seed ticks during the period of several months which many of them lived. Because of the extreme activity of the seed ticks it was impossible to remove this cover for the introduction of water; hence we were obliged to force the latter through the cloth, when it would run down the sides of the bottle. This not only seriously interfered with the seed ticks which were clinging to the glass, but also made it more difficult to determine when the seed ticks were dead because of the dust carried through the cloth by the water and deposited on the glass. This difficulty was surmounted by the drilling of a small hole in one side of the bottle near the bottom. A small pledget of cotton was placed inside the bottle over the irrigating opening to prevent the dry sand from running out when the cork was removed. The dry sand, which had previously been thoroughly washed, dried, and sterilized by heat, was then poured in, carefully shaken down, and leveled off. The sand in those bottles in which ticks were to be kept under dry conditions was then covered with a piece of blotting paper, cut to fit tight in the bottle, on top of the sand, and the eggs were placed on this, thus preventing the latter from being buried should the bottle be accidentally upset. Where the seed ticks were to be kept under moist conditions the sand was well shaken down and leveled off, the cork removed, and the bottle set in a beaker containing water which had been boiled or distilled. After the sand had become thoroughly moistened the cork was replaced and the eggs were placed directly on the sand. This arrangement also made it possible to supply water sufficient for the maintenance of optimum conditions at will without interfering in the least with the seed ticks.

For those eggs and seed ticks kept under outdoor conditions a shelter was provided, modeled somewhat after the instrument shelter used by the United States Weather Bureau. This shelter is rectangular in form, the longer sides being ventilated, thus providing for a free circulation of air around the instru-

ment and materials under observation. Access to the shelter was had by means of a hinged double-walled cover, having a four-inch air space. Inside, a small shelf was provided at one end for the thermograph, and next to this was a zinc pan containing a couple of inches of sand, on which the pill boxes, containing the engorged ticks, were placed during oviposition. At the other end was a rack for holding the bent-neck seed-tick bottles at an angle of about 45 degrees. This was found by experience to be the best position in which to keep them because the seed ticks naturally seek the highest point, which in this case was a rounded surface of clear glass, so that the seed ticks were in a position where they could be readily observed.

LIFE-HISTORY

Although the life-history of the cattle tick is pretty generally known, a brief outline at this point will not be out of place. The engorged, fertilized female is the logical starting point in a consideration of the life-cycle of this species. After dropping to the ground the engorged tick immediately seeks cover, crawling under almost any object that will afford at least partial protection from light. Here, after a resting or maturation period,varying in length with the season of the year, she deposits her eggs (1500 to 4000), usually in a single mass. The length of the oviposition period varies with the temperature of the soil, or other object with which the tick happens to be in contact, and the surrounding air temperature. It may be as little as 9 days or as much as 100 days. The same factors also influence all of the other non-parasitic stages. Depending upon the time of the year and on the temperature, the eggs laid in any particular season may hatch before winter or may go over until the following spring before hatching into the six-legged seed ticks.

Large numbers of the engorged females drop into the grass and weeds along paths followed by stock or on pastures where the host animals are feeding. This, together with the normal habit of the seed ticks of "bunching up" in a large mass or ball on or near the tip of a blade of grass, or the leaf of a weed or small shrub, renders the chance that the resulting seed ticks will find a host extremely good. The regularity of the feeding and resting habits of the cattle contributes much to the certainty of this under natural conditions, for in the ordinary course of events a host animal will probably come within a few days, or weeks, at most. No great hardship is incurred, however, if the host does not appear for several months, for the seed ticks are able to endure a long fast. When a host animal comes into contact with one of these masses large numbers of the ticks cling to the hairs, most of them eventually attaching to the skin, where, within from 7 to 9 days they become engorged with blood. After a short rest they molt, emerging as eight-legged nymphs, which, after an engorgement period of from 5 to 10 days, molt to the sexually mature adults (Fig. 13). These mate and engorge again within from 4 to 14 days, when they drop to the ground for egg-laying. These parasitic stages are much less affected by changes in the air temperature than are the non-parasitic stages, for until the latter part of the final engorgement the ticks are pretty well protected by their location under the hair, next to the skin of

the host, whose body heat tends to counteract the lower temperature of the surrounding air.

THE ENGORGED ADULT

Considerable space is given under this head to a discussion of the internal anatomy because of the light such a study throws on many of the habits and reactions of this species.

The peculiar alimentary system of the fever tick (Fig. 14) consists of from 10 to 12 caeca or diverticula, and is evidently an adaptation to a parasitic life and a liquid diet. The buccal cavity opens posteriorly into the esophagus, from which arise two lateral diverticula, one on either side. Each of these almost immediately branches into 3 or 4 simple caeca. The main trunk, which is also rather short, divides into 4 simple caeca like the tines of a fork. Midway of the main trunk, and arising from its ventral surface, is the intestine, or branch leading to the renal sac and cloaca.

The alimentary tract of a fully engorged female, 8.5 mm in length and 6 mm in breadth, was carefully dissected out under water and the following measurements were made: Right lateral diverticulum, main stem 2 mm to first branch and 16 mm from there to end. Its three branches measured 4, 8 and 10 mm, respectively. Left diverticulum, main stem 3 mm to first branch and 21 mm from there to end. Its four branches measured 4, 5, 8 and 5 mm, respectively. Main trunk, 2 mm to branching of posterior caeca, which measured, beginning on the right side, 15, 18, 19 and 16 mm, respectively. The intestine was 2 mm in length and the renal sac 1.5 mm in diameter. Thus in this tick the total length of the caeca alone is equal to more than eighteen times the length of the engorged tick. The distance from the branching of the lateral diverticula to the extreme end of the longest caecum is 21 mm, or two and a half times the length of the tick.

The following concise statement of the course of these diverticula within the body of the tick is based upon careful dissections, by the writer, of fresh material under water:

The posterior caeca extend parallel along the dorsal wall to the posterior end of the body, where they turn ventrad and traverse the ventral surface to the head, there turning dorsad and caudad and ending blindly on the upper surface, near the head. The main portion of the lateral caeca extends along each side to the caudal end and from there parallel the posterior caeca, usually reaching the head if not turning dorsad and caudad. The branches of the lateral caeca follow a general backward trend, however, rarely reaching the caudal end.

Regarding the movement of the food within the caeca, Williams[14] observed "a very active peristalsis" in the rabbit tick (*Haemaphysalis leporis-palustris*), "at the proximal parts of the diverticula which seemed to drive the blood continuously to the blind end of the sac." The only instance in which the writer was able to observe this action was in a male of *Amblyomma americanum*.

The following notes were made at that time: The peristaltic action of the caeca was quite marked. The action was not regular or rythmic but rather

intermittent or convulsive. The wave-like movements usually started at the extreme end of the caeca and moved toward the esophagus. These waves therefore originated just above the head and traveled to the caudal end of the tick, then back to the head. The constrictions were stronger at the blind end of the sac and decreased in intensity as they proceeded toward the esophagus. After a series of from five to ten convulsions the muscles of the caeca remained quiet for some time, when the action was resumed. During this interval the food particles could be seen flowing back toward the blind end, and this appeared to be the stimulus which set up another action. At no time during the half hour this specimen was under observation were all of the caeca quiet, nor were all of them active at any time. The peristaltic action in that portion of the gut cephalad of the second or last branching was very weak.

These two apparently contradictory observations may be harmonized by assuming that the peristaltic waves travel in either direction, and this would seem to be necessary because of the peculiar pouch-like alimentary system, of which probably only a part is absorptive.

Entirely aside from the emaciation due to the destructive action of the organism causing Texas fever, which is transmitted by this tick, on the red corpuscles of the blood, and that caused by "tick worry" due to the irritation incident to gross infestation, there is a further drain on the vitality of the host because of the actual withdrawal of blood. We may get some idea of this physical drain when we reflect that each of the thousands of ticks on a grossly infested animal becomes fully distended, or engorged, three times in the course of its deveolpment, a period, usually, of less than thirty days. The quantity of blood required for the first two engorgements. while comparatively small for each individual tick, nevertheless is staggering when considered in the aggregate. Here provision need be made by the parasite only for its own bodily growth. With the last, or adult, engorgement, however, it is an entirely different matter, for here the demand for the bodily nourishment is greater and the distension is enormous. The quantity of blood imbibed at this stage must be large enough, not only for the nutrition of the tick itself during the pre-oviposition and oviposition periods, but also for the development, not only of the large number of eggs produced by each female, but of the ovaries themselves. In the spent female these organs are very much larger than the entire tick at the beginning of engorgement (Figs. 7 and 8). Furthermore, the newly hatched seed tick is able to enter immediately upon a fast of several months' duration, even in warm weather, during which it must depend for nourishment upon the stores of food already in the body. In other words, while awaiting a host the seed tick lives upon the food material stored in the egg from which it hatched and which came originally from the host.

The peculiar engorgement habits of this species render almost impossible a direct determination of the actual quantity of blood withdrawn from the host by any individual tick. However, we may arrive at an approximate estimate through the loss in weight of the tick during oviposition. In Table I are given the results of accurate weighing tests on 9 engorged female ticks which were kept in the incubator at approximately 85° F. during the whole oviposition period. The ticks were carefully weighed before being placed in

the incubator, and daily weighings were made of the eggs laid during each twenty-four hours, and as soon as oviposition was completed the spent females were again weighed. As will be observed in the table, the total weight of the eggs produced equaled but 56 per cent of the original weight of the tick, while the total loss was 79 per cent, leaving 23 per cent to be otherwise accounted for. In view of the fact that the food of ticks has a high protein content, one would naturally expect the production of a considerable quantity of nitrogenous waste products, and this is the case, except that all of the solid and liquid portions of this waste are stored in the renal sac and Malpighian tubes and remains there after the death of the tick (Figs. 5 and 6). As no solid or liquid waste materials are excreted by the adult female after final engorgement, we must look to the excretion of water vapor, through respiration, for the larger part of this loss.

The course followed by the Malpighian tubes, which arise as two caeca from the renal sac, is shown schematically in Fig. 2. This is a representation of the excretory system *in situ* in an engorged female 8.5 mm in length, bleached entire with hydrogen peroxid and cleared in xylol. The combimed length of the two tubes was 124 mm.

TABLE I—*Loss in weight of adult female ticks during oviposition, and weight of eggs produced*

Sub-No.	Number of ticks	Weight of ticks	Weght of spent ticks	Total loss		Weight of eggs	Per cent of total weight
				Weight	Per cent		
		Mg.	Mg.	Mg.		Mg.	
80.3	1	337.0	76.9	260.1	77	82.4	24
80.4	1	358.0	81.5	276.5	74	191.8	55
84.11	1	254.0	44.5	209.5	83	162.7	64
84.12	1	283.0	55.4	227.6	80	157.1	52
88.1	1	288.0	57.2	230.8	80	....	....
88.1	1	405.9	98.5	307.4	76	....	....
88.1	1	375.5	67.4	308.1	82	1102.0	61
88.1	1	288.6	60.5	228.1	79	....	....
88.1	1	450.7	85.4	365.4	81	....	....
	9	3040.7	627.2	2413.5	79	1696	55.7

Although no comparative weights are available, it is highly probable that the weight of the newly molted adult female does not exceed 10 per cent of her weight after engorgement. This would place the amount of blood imbibed by each female during the last engorgement at approximately three-tenths of a gram. This estimate is based upon the 9 ticks cited in Table I, whose average weight was 338 mgs. The specimens selected for this test were well-developed, normal ticks of about average size, both large and small individuals being included, as will be seen from the great variation in weight. When this weight is multiplied by the number of ticks engorging upon a grossly infested animal, one of the most potent reasons for the presence of so much stunted, scrubby stock on farms where ticks are plentiful from year to year,

is made evident. The young animal cannot furnish a large number of ticks with such quantities of blood and at the same time make a satisfactory growth; hence is undersized. When it is placed in the dairy, too large a proportion of its feed must be used to support the parasites for it to be profitable to its owner. It would be interesting to know how much extra food is required, throughout the tick-infested area, to support these parasites.

PRE-OVIPOSITION PERIOD

When the female tick drops from the host the ovaries are not yet mature, the eggs appearing as mere buds on the outer wall of the ovaries (Figs. 7 and 8). Some time is required for the development and maturation of the eggs and their passage down the oviducts. This is known as the pre-oviposition period, which varies greatly in length at different seasons of the year. Our records show a variation of from 2 to 56 days, the shorter period occurring in summer and the longer in winter. It is quite probable that had we been able to collect ticks from cattle at Knoxville the latter figure would have been somewhat greater, because the higher temperatures in mail cars and post-offices during the cooler season must have somewhat hastened egg development. That this factor would have made practically no difference during the warmer portion of the year is indicated by the fact that our records on this point closely approximate those obtained by Newell and Dougherty[8] at Baton Rouge, and Hunter and Hooker[6] at Dallas.

While the engorged female ticks are negatively phototropic[5], seeking protection immediately after dropping from the host, and while a very large portion of them do find such protection, there is no evidence that they in any way choose either the time or place for dropping off, this apparently depending entirely upon completion of engorgement. Mere chance and the natural feeding habits of the host seem sufficient to assure the dropping of a greater portion of them under conditions favorable, not only for the tick itself and its eggs, but also for the seed ticks. Undoubtedly a considerable percentage of engorged ticks drop off in locations that are decidedly unfavorable. This is true particularly of those that drop while the host is standing in water or on hard, trodden ground, as where cattle congregate in the shade. In the latter case they may be crushed by the host stepping on them or they may be picked up by birds, several species of which will eat them, before they are able to find protection.

THE FEMALE REPRODUCTIVE ORGANS

The female reproductive organs (Figs. 7 and 8) consist of an ovipositor, which is essentially an eversible tube, receiving at its posterior end the short duct from the seminal receptacle and the two oviducts, right and left. Anterior to this branching it also receives the ducts from the simple, tubular accessory glands, the function of which is not clearly understood. Each of the paired thin-walled oviducts forms a long loop extending dorsal and finally returning almost to the point of origin near where they join the opposite ends of the single tube-like ovary. In a typical engorged female, which had not yet begun egg-laying, but which contained fully developed eggs, each oviduct

was found, on careful dissection, to be 23 mm in length, while the single ovary was 26 mm. The peculiar loop arrangement of these organs has led at least one investigator into the error of believing that "the oviducts are very short"[14]. This is a mistake very easy to make while attempting to trace the internal organs of alcoholic-sectioned material, particularly where, as in this case, the loop is inclined both laterally and posteriorly.

The eggs develop in balloon-shaped, thin-walled sacs around the periphery of the tube-like ovary, and when mature are discharged into the lumen of this tube, down which they pass to the oviducts and finally to the ovipositor. The shell glands, which furnish the protective coating for the eggs, are located just above the mouth parts and consist of four tufts, or bunches, of simple tubular glands, two on either side of the median line. These pour their secretion over a membrane, which is usually hidden between the scutum and capitulum, but which is exposed when the latter is depressed and the mouth parts are retracted, as in egg-laying.

An excellent description of the process of oviposition, as observed by Mr. R. A. Cushman, is given by Hunter and Hooker[6], and the writer cannot do better than quote, as follows:

"When oviposition is about to take place the capitulum is bent downward toward the genital aperture. This exposes a delicate, viscid membrane between the capitulum and the scutum. The membrane becomes distended and is projected out over the capitulum in two rounded lobes, practically covering it. This process is repeated several times before the egg is finally ejected, the membrane being extruded and retracted alternately while the capitulum is lowered and raised. Finally the white, membranous ovipositor is extended, turning inside out, until it touches the distended membrane. The capitulum is now completely hidden. As soon as the ovipositor and membrane have come in contact the former slowly recedes leaving the egg adhering to and partly enveloped by the membrane. The egg remains in this position for a varying length of time. Then the membrane is withdrawn, rolling the egg along for a short distance on the dorsal surface of the capitulum. At the same time the capitulum is raised. Then the processes of distension and contraction of the membrane and the lowering and raising of the capitulum are repeated several times, the eggs being finally completely coated by the viscid substance from the membrane and being finally pushed back and deposited on the anterior edge of the scutum. Each egg is laid in this manner, the tick backing slowly away and leaving the mass of eggs in front of her. The actual time consumed by the tick in laying a single egg is about 30 seconds, while the removal of the egg and the resting period consume from one to several minutes, a much longer resting period being taken at intervals between lots of from 10 to 50 eggs.

"In the manner described a mass of eggs grows steadily in front of the tick, while its body becomes correspondingly smaller as the process proceeds. The gummy secretion holds the eggs together so that the mass looks not unlike a large accumulation of minute brown beads." (See Fig. 3).

On several occasions when normal engorged females were exposed to freezing temperatures, which, however, were not severe enough to cause

death, a few of them suffered complete impairment of the egg-laying function. Frequently they were able to expel two or three eggs, after which further efforts were unavailing. The entire region about the mouth parts and the genital aperture became gummed up with a sticky secretion, probably from the shell glands, which apparently were not injured. Just what organs or functions were disturbed in these cases was not learned. In other instances the shell glands were affected in such manner as to stop the flow of the secretion. The eggs were deposited on the membrane in the normal manner, but instead of being rolled over and over, as while being coated with the viscid secretion, the deposition of each succeeding egg on practically the same spot resulted in the formation of "strings," consisting of a single row of eggs joined end to end (Fig. 9). This adhesion of the eggs to one another in rows is brought about through the fact that the chitinous shell, when it leaves the ovipositor, is quite sticky, but it soon loses this adhesiveness on exposure to the air. The end of each egg when fresh comes into contact with the preceding one, to which it adheres, while the interval of time between successive eggs is sufficient for the remainder of the surface to become dry, thus losing its adhesiveness. On the other hand, the secretion of the shell glands does not harden but retains its stickiness even after long exposure to the air.

RATE OF OVIPOSITION

The rate of oviposition naturally varies with the temperature of the air surrounding the tick and that of objects with which the latter is in contact. The period is shorter during the higher temperatures of midsummer, while the cooler weather of fall, early winter and spring is accompanied by a lengthening of this period. Our records for ticks kept outdoors show a variation from 9 days, occurring on several occasions during the summer months, June to early September, to 122 days for a tick dropping from the host during January. The latter, however, is an extreme case, and not a continuous record. This tick laid a few eggs, beginning early in January, during a warm spell which was followed by cooler weather, the latter prevailing until early spring without being cold enough to be fatal to the tick, which eventually laid her full quota of eggs.

In Table II are presented the monthly averages of individual oviposition records for 1142 engorged female ticks kept outdoors, and includes exposure to all kinds of temperature conditions, occurring in six consecutive winters and the five intervening summers. Monthly averages are shown for all months except January and December, during which months all adult engorged ticks exposed were killed by freezing before egg-laying was completed, with one exception, and in this case the record is open to question, and hence is not included. As the table shows, there was a gradual reduction in the length of the period from February to June, then a gradual increase through the summer and fall to October. The smoothness of the curve is broken by the figures for November, for which month the average is but 23 days, This figure is undoubtedly too small, for it is less than the similar periods for September and October. That it should be larger is evident from the fact that 80 per

cent of all the ticks dropping from the host during this month, for the six years included, were killed by freezing before oviposition was completed. Furthermore, the fourteen ticks whose records were used in securing this average dropped from the host during November, 1908, in which month 66 per cent of all adult ticks exposed were killed by freezing. It is also probable that the lives of some of the ticks not killed outright by cold were much shortened. This latter factor probably also influenced the length of the oviposition periods of many other ticks dropping from host from the middle of October to the latter part of February.

TABLE II—*Summary of the individual oviposition records of* 1142 *engorged female ticks*

Dropped from host	Number of ticks	Average number of days
January	0	0
February	124	49
March	114	36
April	133	29
May	150	18
June	144	13
July	172	14
August	89	14
September	133	25
October	69	37
November	14	23
December	0	0
	1142	25

In the making up of Table II the records of the individual ticks were used. Approached from the standpoint of eradication, however, the maximum oviposition period assumes greater importance than the average, or that of the individual ticks. In Table XIII the lot, or group, of ticks, rather than the individual, is the unit, the extreme dates of the beginning and ceasing of egg-laying being used regardless of whether they were obtained from the record of a single individual or not. This accounts for the difference in the length of the oviposition period between Tables II and XIII, on the one hand, and Table IV on the other. Using these extremes, we get the figures shown in Table IV, which are derived from the records of 1520 ticks, comprising 205 lots. The average here is 32 days as compared with 25 days, the average of the individual records of 1142 of the above ticks.

All of the foregoing records were obtained under outdoor conditions. For comparison with these, and to learn the effect of constant high temperatures, 26 ticks were confined at various times in the incubator, where an attempt was made to maintain a temperature of 85° F. during the entire oviposition period. The results are shown in Table III. The length of the oviposition period varied from 4 to 10 days, averaging 7.42 days, during which an average of 2113 eggs were laid by each tick. This is at the rate of

Table III—*Rate of oviposition of 26 engorged female ticks kept in the incubator at* 85° *F.*

Sub-No.		Number of eggs laid each twenty-four hours											Average per day
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Total	
43.1	1	102	632	465	97	8	1	.....	....	....	....	1305	217.5
	2	329	502	415	270	90	18	11	....	....	....	1635	233.5
	3	628	457	428	234	79	32	12	....	....	....	1870	267.1
	4	544	447	273	119	47	1	.....	....	....	....	1431	238.5
	5	541	344	105	7	.....	.....	.....	....	....	....	997	249.2
46.	1	38	635	700	631	667	397	212	86	54	19	3439	343.9
	2	86	649	818	812	659	364	249	125	78	34	3874	387.4
	3	485	689	712	646	402	323	201	126	57	12	3653	365.3
	4	730	1006	791	706	395	241	101	65	30	6	4071	407.1
	5	145	874	797	880	577	370	121	77	8	28	3877	387.7
	6	449	746	802	623	343	293	139	88	25	21	3529	352.9
50.1	1	316	720	573	367	171	47	29	....	....	....	2223	317.5
	2	404	747	505	279	118	27	8	7	....	....	2095	261.8
	3	147	977	945	411	252	91	24	....	....	....	2847	406.7
	4	780	494	232	84	20	12	.....	....	....	....	1622	270.3
	5	623	762	402	115	16	9	12	20	....	....	1959	244.8
51.	1	612	197	106	34	18	.....	.....	....	....	....	967	193.4
	2	794	343	278	145	62	32	10	....	....	....	1664	237.4
	3	834	354	82	27	19	29	10	....	....	....	1355	193.6
	4	495	334	108	54	21	29	57	....	....	....	1098	156.8
	5	642	317	110	47	18	12	.....	....	....	....	1146	191.0
55.	1	217	495	428	264	75	1	.....	....	....	....	1480	246.6
	2	235	381	707	455	318	145	64	8	....	....	2313	289.1
	3	144	14	416	673	160	60	26	....	....	....	1493	213.2
	4	101	7	685	555	102	38	34	7	....	....	1529	191.1
	5	134	186	778	255	102	22	.....	....	....	....	1477	241.1
Average		406	512	487	338	182	100	51	23	10	5	2113	284.8

285 eggs per day. Considering the daily averages the largest number of eggs laid in any twenty-four hours were produced on the second day. From this

Table IV—*Monthly averages of maximum oviposition periods of* 1520 *engorged female ticks, comprising* 205 *lots*

Dropped from host	Number of ticks	Average number of days
February	159	51
March	93	42
April	83	32
May	161	24
June	139	16
July	92	14
August	245	18
September	150	31
October	270	46
November	128	50
	1520	32

point there was a gradual decrease to the end, the numbers when plotted describing a smooth curve. The largest number produced by a single tick within any twenty-four-hour period was 1006. These were laid on the second day of the oviposition period of a tick which produced a total of 4071 eggs, an average of 407 eggs per day for the total period. The smallest total number of eggs produced by a single individual was 967.

FATAL TEMPERATURES

During each winter that this investigation has been in progress many of the engorged female ticks placed outdoors for oviposition have been killed by freezing; hence a study was made of the conditions surrounding these ticks at such times. The highest temperature fatal to any of the exposed ticks was 24° F. The percentage of ticks killed by this and other temperatures down to 19° F. varies greatly. Whether this and other temperatures above it are fatal depends largely upon conditions other than temperature, as will be explained later. It will be noted in Table V, which is based upon the records of 62 lots of ticks and covers five winters, that practically all of those exposed to 17, 16, 13 and 8 degrees, respectively, were killed. Reference to the table shows that a temperature of 12° F. was fatal to but 75 per cent of the 8 ticks exposed, but this apparent anomaly is explained by the fact that but 2 of these were in pill boxes, while the others were protected by a covering of dry chaff. Four of the 6 thus protected, together with the 2 in the pill boxes, were killed. Eliminating the 6 protected ticks, the mortality at this temperature becomes 100 per cent.

TABLE V—*Number and percentage of engorged female ticks killed by exposure to various temperatures, from* 8° *F. to* 24° *F*

Temperature	Number of ticks exposed	Number of ticks killed	Per cent of ticks killed
Degrees F.			
24	40	25	62
23	18	6	33
22	59	17	29
20	24	12	50
19	56	43	76
17	150	150	100
16	38	33	91
13	128	125	97
12	8	6	75
8	102	102	100

That 2 of the 6 ticks protected by a covering of dry chaff, when subjected to a temperature of 12° F., survived, emphasizes the great value, to the species, of such covering. In another experiment 10 engorged females were placed on dry litter, from a stock car, in a glass cylinder and kept under shelter but subject to outdoor temperature conditions. This lot was prepared January 2. and on the 8th all of them had buried themselves in the

litter. In spite of the fact that the mercury fell to 17° F. on January 27, and to 16° F. on February 6, a few seed ticks hatched from eggs laid by these ticks and lived until the following August. Because the material in the cylinder was not disturbed after the ticks were placed in the litter it is not known whether the adult ticks laid the eggs soon after being placed on the litter or survived the winter, laying the eggs in the spring. Ticks exposed at the same time were killed by cold. The conditions obtaining in this test simulate very closely those to be found in stables and sheds where the litter is left undisturbed throughout the winter. It shows clearly the possibility of carrying infestation over from one year to another under such conditions.

In other tests when the mulches became wet, or even damp, the ticks so protected were killed by temperatures not fatal to ticks kept in dry pill boxes. In the tick box previously described the pill boxes were frequently piled up several deep on dry sand. When, as occasionally happened, this sand became moist from rain beating into the shelter, the ticks in the bottom boxes, which became wet, were killed by temperatures not fatal to those in dry boxes.

The application of this factor to natural conditions is seen in the normal habit of the engorged female of hiding immediately after dropping from the host. This action brings her into contact with the soil, which during the colder months is nearly always moist or even wet. Under these conditions a higher temperature would be fatal to her than if she were dry. Thus a covering of chaff or other litter is, when dry, decidedly protective, but when wet has a pronounced opposite effect.

Another factor which appeared to exert considerable influence on the mortality is the stage of oviposition at the time the tick is subjected to the low temperature. Engorged ticks that have not begun egg-laying are able to survive low temperatures fatal to those that have laid part of their eggs.

THE EGG STAGE

As before stated, the eggs are protected from excessive drying by a coating of a viscid, glandular secretion, applied just after they leave the ovipositor (Fig. 10). This coating possesses the property of retaining its viscidness with long exposure to the air of the humid portions of the tick region. The conservation of moisture, upon which very largely depends the ability of the embryo within the egg to survive the winter, and hatch the following spring, is based to a large extent upon the presence of this coating. Each egg has its individual coating, and to that extent all are equally protected. However, because of the peculiar oviposition habits of the ticks and the adherence of the coated eggs to one another, those on the outside of the mass are more exposed than those within it and frequently dry up completely while those inside are still fresh and plump. We may thus safely conclude that because of this coating there is, under ordinary conditions, very little transfer of moisture from the plump eggs within the mass to the dry ones on the outside. Of course long-continued desiccation will remove the moisture from all of them. This is probably the explanation of the absence of the

tick from large areas of the arid portion of the Southwest, where it undoubtedly could exist so far as the temperature is concerned.

Because of the vital importance of this coating, as a means of preserving the viability of the eggs under unfavorable conditions, an attempt was made to secure eggs wthout it. As no practical method was available for preventing the application of this coating, without producing abnormal conditions for the tick, it was decided to wash the coating from eggs laid in the normal manner. For this experiment the eggs from two lots of 10 normally engorged female ticks which were at about the same stage of embryonic development were selected. The eggs from one lot of ticks were transferred to a tared shell vial, weighed, and placed over sulphuric acid in a desiccator. The eggs from the other lot, after being weighed in a similar tared shell vial, were transferred to a short glass tube, each end of which was closed with a piece of muslin, and the whole connected up to the water faucet by means of rubber tubing. A constant stream of water was kept flowing through the tube and over the eggs for twenty-four hours, when the coating was removed to such an extent as to allow the mass to break up readily. They were then spread out in a thin layer for a few minutes to dry off most of the adhering moisture. They were then transferred to the shell vial again, weighed, and placed in the desiccator with the other lot. These eggs were found to have gained slightly in weight from the washing, probably because of the absorption of water after the removal of the greater part of the gelatinous coating. This supposition is borne out by the fact that the eggs were observed to be somewhat larger after washing than before. This absorptive capacity of unprotected eggs has been observed during dissection under water, when fully developed eggs, without the chitinous coating, which escaped through accidental rupture of the walls of the ovary or oviducts, swelled to two or three times their normal size.

The vials containing the eggs were weighed at irregular intervals for 41 days, by which time they had reached fairly constant weight, as shown in Table VI. Plotting these figures we obtain the curves shown in Fig. 1. The slight gain in weight of the washed eggs, due to the absorption of water, is followed by a rapid loss, which is approximately uniform up to 50 per cent. From this point the loss is slight, and it practically ceases at 56 per cent. In the case of the unwashed eggs the rate is also nearly uniform, but very much slower than for the washed eggs. The average daily loss up to the 50 per cent line is about 2.5 per cent per day as compared with 7 per cent for the washed eggs. As measured by elapsed time the 50 per cent loss in weight of the washed eggs required but 6 days, while for a similar loss 20 days was required in the case of the unwashed eggs.

The daily rate of loss of moisture becomes very important when viewed in the light of the results of some earlier experiments, in which it was found that when approximately 25 per cent of the original weight of the egg mass was lost by drying none of the eggs hatched. Examining the curves with this point in mind, we find that the washed eggs reached the critical point in 3 days, while 10 days was required with normal eggs.

Our results, as well as those of other investigators, show that a considerable percentage of tick eggs will hatch after as much as from 20 to

TABLE VI—*Loss in weight of washed and unwashed eggs when kept over sulphuric acid in a desiccator*

Date		Eggs washed twenty-four hours			Unwashed eggs		
		Weight of eggs	Accumulated loss		Weight of eggs	Accumulated loss	
		Grams	Grams	Per cent	Grams	Grams	Per cent
March	22	1.2110	....	....	....	....	....
	23	1.2516	+.0406	+3.0	.9220	....	....
	24	1.1271	.0839	7.0	.8950	.0278	3.0
	26	.9093	.3017	25.0	.8423	.0797	8.7
	28	.7668	.4442	36.7	.7945	.1275	13.9
	29	.6695	.5415	44.7	.7681	.1539	16.7
	30	.6127	.5983	49.4	.7329	.1891	20.7
April	1	.5791	.6319	52.2	.6898	.2322	25.2
	2	.5663	.6447	53.3	.6593	.2627	28.6
	4	.5528	.6582	54.4	.6038	.3182	34.7
	5	.5486	.6624	54.7	.5744	.3476	37.7
	6	.5461	.6649	55.0	.5498	.3722	40.4
	8	.5443	.6667	55.2	.5173	.4647	43.9
	11	.5400	.6710	55.4	.4655	.4565	49.6
	15	.5386	.6724	55.6	.4262	.4958	53.8
	20	.5376	.6734	55.7	.4081	.5139	55.8
	26	.5363	.6747	55.8	.4000	.5220	56.7
May	2	.5340	.6770	56.0	.3949	.5271	57.2

25 days' submergence in water. In our own case, and so far as can be discerned from the reported results of others, all of these tests were made with normal eggs in quiet water. Under such circumstances the viscid coating of the eggs is left intact and the masses do not break up. The conditions existing in pastures where there are pools of standing water are thus closely similated. However, where the eggs are in running water, particularly if it be moving swiftly, the coating of the individual eggs is washed away and the masses are broken up and scattered. Such eggs have little chance of hatching because of the absorption of water.

THE INCUBATION PERIOD

The incubation period, profoundly influenced as it is by temperature, varies greatly with the seasons of the year. The shortest period, under outdoor conditions, was 24 days, for eggs laid by ticks dropping from the host July 5, while the longest was 252 days, for eggs laid by ticks maturing September 20. August occupies a unique position as regards length of incubation period of eggs from ticks dropping during that month. July is the only month having a shorter period, and it ranks third for length, being exceeded in the latter respect only by September and October. This condition is brought about by the fact that the eggs laid by ticks dropping before about the 28th of the month normally hatch before winter, while those produced by ticks maturing after that date do not hatch until the following spring. Whether they will hatch even then is very largely a question of the efficiency of the viscid coating of the eggs as a means ot conserving moisture throughout the long period

during which embryonic growth is inhibited by low temperature. The foregoing figures on length of incubation period are the extremes and are taken from Table XIII. Table VII, on the other hand, gives the monthly averages for the eggs from the lots of ticks dropping during the respective months, and covers the total period of the investigation. It includes the records for 158 lots of ticks, aggregating 1082 individuals. As will be noted, no records are given for November, December or January. This apparent omission is due to the fact that during these months all of the adult ticks exposed were killed by freezing before egg-laying, or the eggs failed to hatch.

TABLE VII—*Average length of incubation period of eggs kept on moist sand and dry sand outdoors*

Month	Moist sand			Dry sand		
	Number of lots	Number of ticks	Incubation period in days	Number of lots	Number of ticks	Incubation period in days
February	14	115	94	9	41	94
March	9	52	74	8	41	72
April	7	49	57	5	34	55
May	9	82	39	9	79	40
June	9	69	29	9	70	28
July	10	49	32	10	43	37
August	16	134	69	12	95	45
September	14	76	212	1	7	230
October	6	38	208	1	8	217
	94	664	91.6	64	418	57

As before stated, the eggs from each lot of ticks were divided into two fairly equal lots, one of which was placed on moist sand and the other on dry sand and both subjected to otherwise identical conditions. The influence of this treatment on the average length of the incubation period for the various months is shown in Table VII. When these monthly averages are compared no pronounced variation is seen that can be attributed to the treatment, except for the month of August. This variation is explained by the fact that the moist-sand column includes three lots of eggs laid by ticks dropping from the host after the 28th of the month, these eggs going over until the following spring before hatching, while the corresponding lots on dry sand failed to hatch at all. Eliminating these three lots, which required 183, 197 and 198 days, respectively, for incubation, we find the averages of the two columns as close as those for the other months, being 48 days on moist sand and 45 days on dry.

OVERWINTERING EGGS

From the standpoint of the influence of lethal temperatures on the eggs the ticks dropping from the host at different seasons of the year may be divided into three classes. This phase of the subject was treated in a former bulletin of this Station, from which the following quotation is made[2]: "Those ticks which become engorged and drop from the host animal after the last

fatal temperature (23° F.) in the spring, and before that date in late summer, when the daily mean temperature falls to 75° F. or lower, will lay eggs which hatch the same season. This period, at Knoxville, extends from about February 1 to about August 28, and becomes gradually longer as one proceeds southward. Ticks dropping from the host during the period when the daily mean temperature is between 75° F. and 69° F. lay eggs which may hatch the same season or may go over until the following spring, depending upon the temperature during the fall and winter months. Ticks dropping from the host after the temperature has fallen below 69 degrees may lay eggs, if not killed by freezing, but these eggs will remain dormant during the winter, hatching in the spring. In our investigations here we have found that engorged ticks dropping from the host during a short period in late fall have their egg-laying interrupted several times by low temperatures and are finally killed by freezing before the process is completed. Those eggs which they do lay fail to hatch." These conclusions have not been altered by the results of later investigations.

TABLE VIII—*Overwintering eggs on moist and dry sand that failed to hatch*

Month	Eggs on moist sand		Eggs on dry sand	
	No. of ticks	No. of lots	No. of ticks	No. of lots
August	....	....	16	2
September	....	....	57	11
October	113	12	153	19
November	90	7	98	10
December	10	1	....	....
January	53	4	....	....
February	....	....	3	1
	266	24	327	43

With the exception of December and January, the larger percentage of the overwintering eggs that failed to hatch were those kept on dry sand, as is shown in Table VIII. This exception is due to the fact that the ticks that dropped from the host during these months laid but few eggs before being killed by freezing. In each case the quantity of eggs produced was too small to divide; hence all were placed on moist sand.

THE SEED TICK

The singularly appropriate term "seed tick" is applied to the first stage of all ticks. That it is preferable to "larval stage" is recognized by anyone who has observed the striking resemblance of this stage to the seeds of many plants.

When the seed tick emerges from the egg it is six-legged (Fig. 11), colorless and nearly transparent, but after a short exposure to the air the chitin assumes a reddish-brown tint, the body being slightly darker than the legs. At about the middle of the incubation period the renal sac and the Malpighian tubes first appear as chalky white objects, showing through the chitinous

eggshell. These organs, which constitute the excretory system, are filled with the waste materials of embryonic growth, consisting mostly of crystals of uric acid, which are voided as small white drops soon after hatching. When several thousands of the seed ticks are confined in a bottle the inside of the glass becomes coated with this material, after a few weeks, to such an extent as to render difficult observation of the ticks within.

The massing, or bunching, of the seed ticks, which is the normal habit, is the direct result of the peculiar oviposition habit of the adult tick. The seed ticks in such masses are in constant motion, and this motion is probably accompanied by a change in position of the individuals, those on the outside working in toward the middle of the mass and forcing the others out, in a manner similar to the clustering of honeybees.

Some of our results indicate that certain individuals of a large mass of seed ticks under unfavorable conditions as to moisture, outlive similar individuals of a smaller mass enjoying more favorable moisture conditions. This may be attributed to the influence of the size of the mass in modifying the humidity of the air surrounding the individual tick.

While awaiting a host the seed ticks cling, by means of the second and third pairs of legs, to the support on which they are resting, which under natural conditions is usually some form of vegetation. This arrangement leaves the first pair of legs free and whenever the ticks are disturbed these are waved violently in the air in much the same manner that many insects wave their antennae. This habit early led observers to conclude that this appendage was the seat of some sensory function. Haller, in 1881, described a peculiar sensory structure located on the external dorsal surface of the terminal article of the first pair of legs, which later writers have designated as "Haller's organ" (Fig. 12). As yet it is the only organ possessed by ticks which has a clearly defined sensory function. Hindle and Merriman[5] performed some extremely interesting and ingenious experiments on the chicken tick (*Argas persicus*) by which they prove that "the function of this organ is certainly olfactory." But they immediately utter a caution against too hastily considering this as the only possible function, wisely leaving this question open for further investigation. Their work, however, has shown very clearly that this organ "is essential to the tick in the discrimination of its host." In the light of these experiments the action of the seed ticks in excitedly waving their forelegs when disturbed becomes intelligible.

The legs of all stages of all ticks terminate in a pair of hook-like claws well adapted for clinging to rough surfaces. Between the bases of these claws is a large pad, or pulvillus, which not only enables them to cling tenaciously to a smooth surface, but to move over it rapidly. These adaptations, together with their great activity, render it almost certain that a very large percentage of the individuals in a mass will be "picked up" by any object, animate or inanimate, which comes into contact with the mass. The habit of grasping any object which comes into contact with them, whether animate or inanimate, shows conclusively that the olfactory sense is not exercised by the seed ticks until they get on the host and seek a place for attach-

ment. That it does come into play at this juncture is shown by the refusal of unmutilated ticks of certain species to attach to any object other than the particular species of host animal on which they are normally parasitic.

TABLE IX—*Seed-tick longevity as influenced by season and moisture, based on month in which the seed ticks were hatched*

Month	Moist sand		Dry sand		Moist and dry sand	
	Number of lots	Days	Number of lots	Days	Number of lots	Days
March	4	102	....	....	4	102
April	8	85	1	37	9	79
May	10	88	4	78	14	86
June	30	118	20	141	50	127
July	8	179	8	166	16	173
August	6	253	5	238	11	246
September	10	262	8	225	18	245
October	2	288	1	184	3	253
November	1	224	....	....	1	224
	80	149	47	163	126	154

That seed-tick longevity is profoundly influenced by temperature is seen in Table IX, in the last column of which is shown the average life of the seed ticks hatched during the various months of the year, under the climatic conditions prevailing at Knoxvlle. The shortest average period is that for April, when the seed ticks lived but 79 days, while the longest is that for October, 253 days. The longevity of the seed ticks hatching during March, April and May is shorter because they hatched from eggs laid the previous fall or late summer, which were exposed to the cold of the long dormant season.

Entirely aside from the effect of cold on the eggs, the long-continued drying while the temperature is below the point where embryonic growth may take place, has a decidedly debilitating effect on the seed ticks hatching from overwintering eggs, as is seen in Table IX, where the month in which the eggs hatched is the basis of classification. The same data, tabulated on the basis of the month in which the adult ticks dropped from the host, are presented in Table X. This table gives the data on which eradication must be based, for in calculating the date on which seed ticks will disappear from a given pasture we must figure from the date on which the infested cattle were removed from the pasture, under the starvation plan. Where dipping is practiced the date on which the animals ceased to drop engorged ticks is the basis of calculation.

Glancing at this table, we see that seed ticks hatching from eggs laid by engorged ticks dropping during July live longer than those from any other month. All of the eggs from July ticks hatch before winter, and as metabolism is either entirely suspended or at a very low ebb during several months of low temperature, the limited supply of energy stored in the bodies of the seed ticks is used at a much slower rate than when higher temperatures pre-

TABLE X—*Seed-tick longevity, tabulated on the basis of the month in which the adult ticks dropped from host*

Month	Moist sand		Dry sand		Moist and dry sand	
	Number of lots	Days	Number of lots	Days	Number of lots	Days
February	14	105	8	132	22	114
March	8	116	7	124	15	113
April	6	124	5	159	11	140
May	4	194	6	163	10	175
June	4	196	4	173	8	184
July	8	255	6	239	14	248
August	14	240	8	216	22	221
September	16	99	1	25	17	94
October	6	110	1	53	7	99
	80	151	46	166	126	157

vail; hence the longer life. The average longevity for August, which ranks second, is 28 days shorter than that for July. As will be remembered, the eggs laid by a part of the ticks dropping during this month do not hatch until the following spring, and three such lots entered into the foregoing average. With these three eliminated, however, the average is still 6 days shorter than that for July. The shortest period is that for September, for which the seed-tick longevity is but a little more than a third of that for July. But when we add together the incubation and seed-tick periods we find that September is exceeded in length only by October, and that July has dropped to fourth rank (Table XI). That the shortening of seed-tick longevity by cold and desiccation during long-continued low temperatures is not confined to seed ticks hatching from eggs deposited in the fall is shown in the averages for February and March. During these months oviposition is likely to be interrupted several times by low temperatures, not low enough, however, to prove fatal to the adult ticks. Even in the warmer intervals egg-laying does not attain its maximum rate; hence the masses are smaller and the individual eggs more exposed. In addition to this there exists the possibility of derangement of the shell glands, which, as will be recalled, are particularly susceptible to injury by cold. Thus, a considerable portion of the fall- and winter-laid eggs are destroyed by cold and desiccation, and those that do hatch are likely to yield seed ticks of rather low vitality, whose chances of attachment to a host are much poorer than those of the more vigorous summer-hatched individuals.

In considering these data from the standpoint of seed-tick longevity we find the averages for February, March and April on dry sand to exceed those for the corresponding months on moist sand. For this we can give no explanation, for with the exception of February the numbers of lots of seed ticks are approximately equal, and an attempt was made in all cases to apportion equal masses of eggs to the two different moisture conditions. During the remaining months the seed ticks on moist sand outlived those on dry sand.

TABLE XI—*Monthly averages, in days, of oviposition, incubation, seed-tick, incubation and seed-tick, and total periods, on moist and dry sand*

Month	Oviposition	Incubation		Seed-tick		Incubation and seed-tick		Total	
		Moist	Dry	Moist	Dry	Moist	Dry	Moist	Dry
February	51	93	93	107	132	200	225	222	251
March	42	74	72	116	124	190	197	200	209
April	32	58	55	130	159	188	214	190	218
May	24	41	40	194	163	235	202	243	202
June	16	30	31	215	173	245	204	228	207
July	14	33	31	255	239	286	270	291	272
August	18	74	42	226	216	301	245	291	250
September	31	210	230	98	25	331	255	317	258
October	46	208	217	110	53	315	270	297	275
Average	32	105	62	154	166	259	228	265	234

From May to August, inclusive, the differences are slight, but they become very pronounced in September and October. This is not surprising when we remember that nearly all of the lots of eggs laid by ticks dropping during these months, and exposed on dry sand, failed to hatch at all, for the same unfavorable influences that destroyed so many developing embryos could naturally be expected seriously to weaken those which survived. In eradication work such dry conditions are likely to be found only in the semi-arid regions of the Southwest, where this is probably the most potent factor in limiting the natural distribution of the tick. That this region was annually reinfested, through the free movement of ticky cattle from the permanently infested region, prior to the establishment of the Federal quarantine line, can hardly be questioned. That it was not originally included within the quarantined area, although much of it was south of the isotherm of 59° F., which marked the northern limit in the more humid eastern territory, must be attributed to this high mortality of embryos and low vitality of seed ticks, preventing permanent infestation.

LONGEVITY OF SEED TICKS FROM OVERWINTERING EGGS

With seed ticks kept on moist sand it was found that those hatching the same season enjoyed an average longevity of 176 days, while those from overwintering eggs lived but 94 days. On dry sand the average for eggs hatching the same season was the same as for those on moist sand, while those from overwintering eggs lived but 39 days. Bearing these facts in mind, we are probably safe in concluding that, so far as seed-tick longevity is concerned, throughout the humid portions of the tick area the average humidity of the air is sufficient to overcome the unfavorable influences of dry sand, when the eggs hatch the same season they were laid. On the other hand, with overwintering eggs on moist sand the average seed-tick longevity is reduced nearly one-half, while on dry sand it is but little more than one-fourth as long as for those hatching before winter.

MORTALITY OF SEED TICKS FROM EXTREME COLD

With the possible exception of the extreme northern portion of the quarantined area the winter temperatures are rarely severe enough to destroy the seed ticks. That they are occasionally, however, is clearly shown in our records. During the six winters for which we have data, 80 lots of seed ticks, each consisting of several thousand individuals, were exposed to low winter temperatures. The results of such exposure are shown in Table XII. The mortality under the two moisture conditions is seen to be not widely different,

TABLE XII—*Mortality of seed ticks from low temperature*

Temperature	Percentage of seed ticks killed		
	Moist sand	Dry sand	Total
Degrees F.			
13	83	80	82
12	0	0	0
8	38	54	46
4	100	100	100
2	100	100	100

from which we may conclude that at extreme low temperatures moisture, or the lack of it, has little influence on longevity. When the low temperature is accompanied by a light blanket of snow this offers little or no protection to the seed ticks because of their habit of climbing to the top of the support on which they happen to be resting. Here they would be completely exposed to the cold. On the other hand, if the snowfall be deep enough to cover them before the extreme cold appears they will probably take little or no harm from the short cold snaps characteristic of this region. However, along the northern border of the tick area it is probable that the cold spells last long enough to be fatal even with this protection.

SUMMARY

The original Federal quarantine line was established along the northern boundary of the region permanently infected with Texas fever. In the eastern part of the country this line followed pretty closely the isotherm of 59° F. In the more arid region of the Southwest it bent sharply southward along the line of 60 per cent humidity.

Sporadic outbreaks of the fever occurred north of this line, at irregular intervals, always following the introduction of Southern cattle.

The relation of the tick to the Texas fever was first clearly demonstrated by Drs. Smith and Kilborne, in 1893. They established the fact that the disease was caused by a protozoan organism, transmitted from sick animals to sound ones by seed ticks developing from eggs laid by ticks engorging on infected animals.

All rational eradication methods must be based on a knowledge of life-history. The two most prominent methods are "starvation" and "dipping".

The latter is best adapted to free-range territory and the former to regions where agriculture is more highly developed.

The parasitic stages of ticks are little affected by changes in air temperature. These require, respectively, 7 to 9 days for seed-tick engorgement, 5 to 10 days for nymphal engorgement, and 4 to 14 days for the final, or adult, engorgement.

The non-parasitic stages vary greatly with the season and temperature. The pre-oviposition period may last but 2 days in midsummer or it may be prolonged to 56 days in winter and spring. The oviposition period varies from 9 to 122 days under similar conditions.

Each tick engorges with blood three times in the course of its development. The amount of blood imbibed at the first two engorgements is comparatively small, but the quantity required the last time is enormous.

The alimentary system of the tick consists of from 10 to 12 caeca, or blind sacs, which provide large storage capacity. Movement of the food particles within these caeca is accomplished by peristalsis.

No waste materials are excreted by the adult tick after final engorgement. Such materials are stored in the renal sac and the Malpighian tubes, mostly in the form of crystals of uric acid, which remain there after death.

Much of the stunted stock on farms in the tick area may be attributed to the physical drain caused by gross infestation with ticks, by irritation due to the bites of these ticks, and by the destruction of the red blood corpuscles by the fever organism.

Engorged adult ticks are negatively phototropic, hiding immediately after dropping from the host, thus protecting themselves from natural enemies and providing favorable conditions for the eggs and the seed ticks developing therefrom.

The eggs, which are still immature when the tick drops off, develop as buds around the periphery of the single tube-like ovary and receive a protective coating of a viscid secretion, from the shell glands, after they leave the ovipositor.

The normal functioning of the reproductive system is sometimes inhibited by cold; at other times the ovaries are not affected, but the shell glands cease to provide their secretion, without which the eggs are produced in "strings". Such eggs never hatch.

The rate of oviposition varies with temperature. The average daily rate for 26 engorged ticks kept in the incubator at 85° F. was 285 eggs, the extremes being 156.8 and 407.1 eggs, respectively. The average number of eggs produced by each individual tick was 2113, varying from 967 to 4071 eggs. The largest number produced within any twenty-four-hour period by a single tick was 1006 eggs.

Engorged adult ticks exposed to temperatures of 24° F. or lower may be killed by freezing. Those under dry conditions will survive temperatures fatal to those under moist conditions, while partly spent females are more easily killed by cold than those that have not yet begun egg-laying.

Ticks protected by a covering of dry litter will survive very much more cold than those not so protected, but moist litter offers no protection at all.

Eggs protected by the viscid secretion from the shell glands retain their moisture very much longer than those without it. Those eggs from which this coating has been washed are liable to absorb sufficient water to destroy the embryos, if they remain submerged.

The incubation period of the eggs varies from 24 days—the record of a lot of eggs laid by ticks dropping from the host on July 5—to 252 days for eggs laid by ticks maturing September 20.

Eggs laid by ticks dropping from the host before August 28 will hatch before winter, while of those laid by ticks dropping after this date a few may hatch the same season, the remainder going over until the following spring. Whether they will hatch then depends upon the effectiveness of the viscid coating of the eggs in preventing excessive loss of moisture.

Probably many of the eggs exposed to extreme cold are destroyed. In our experiments all eggs exposed to 2° F. were killed. It is very difficult, however, to dissociate this effect from that of excessive drying during the long dormant season.

The renal sac and Malpighian tubes of the newly hatched seed ticks are filled with the waste products of embryonic growth, and these are excreted in small white drops soon after hatching.

The six-legged seed ticks immediately after emergence are able, if necessary, to fast for several months while awaiting a host animal. Our record of greatest seed-tick longevity is 298 days.

The habit of massing, or bunching, of the seed ticks near the top of vegetation is decidedly beneficial to them. This places them in a position favorable for getting on the host animal, where they may attach. It also undoubtedly helps to modify the humidity of the air surrounding the individual ticks, thus enabling them to live longer than if not so massed.

The terminal article of the first pair of legs of ticks bears the only sensory structure (Haller's organ) which ticks are known to possess. While awaiting a host the seed ticks hold to their support by means of the second and third pairs of legs, meanwhile waving the first pair about excitedly whenever disturbed, apparently in an effort to locate a host. This organ is probably the means of discriminating between their host and other objects.

Seed ticks hatching from eggs laid by engorged ticks dropping during July live longest, while those from September-maturing ticks are the shortest lived, the longevity in this case being about one-third that of those from July ticks.

Within the humid portion of the tick area humidity is probably not an important factor in seed-tick longevity when the eggs hatch the same season that they are laid.

The average longevity of seed ticks hatching from overwintering eggs is 94 days, while that of seed ticks from eggs hatching before winter is 176 days. This indicates a debilitating effect on the developing embryos due to cold and drying during the long dormant season.

Seed ticks are able to survive the ordinary winter temperatures of the tick area, except along the northern border. A temperature of 4° F., however, is fatal to all seed ticks.

TABLE XIII—*Detailed information concerning 2315 engorged female ticks kept under outdoor conditions at Knoxville. The facts cited and conclusions reached in this bulletin are based chiefly upon the data contained in this table*

Sub-No.	No. of ticks	Date of collection	Oviposition period			Moist or dry	Incubation period	Seed-tick stage			Total days	Remarks
			Began laying	Ceased laying	Da's			Hatching	Dead	Days		
19.	10	1906 Aug. 27	1906 Aug. 31	1906 Sept. 14	14	M.	26	1906 Sept. 26	1907 June 17	264	294	
21.1	1	Sept. 13	Sept. 17	Oct. 30	43	M.	221	1907 April 26	June 10	45	270	
21.2	7	Sept. 13	Sept. 17	Sept. 26	9	M.	38	1906 Oct. 25	July 7	255	297	
22.1	8	Sept. 26	Sept. 29	Oct. 25	26	M.	177	1907 Mar. 25	July 25	121	301	
22.2	7	Sept. 26	Sept. 29	Oct. 25	26	D.	230	May 16	June 10	25	258	
23.1	7	Oct. 3	Oct. 8	Nov. 1	24	M.	184	Apr. 10	Aug. 6	118	307	
23.2	8	Oct. 3	Oct. 8	Nov. 1	24	D.	217	May 13	July 5	53	275	
24.	8	Oct. 12	Oct. 15	Nov. 12	27	M.	183	Apr. 17	Aug. 12	117	273	
25.2	10	Oct. 25	Oct. 31	Dec. 18	48	D.	....	No hatch	....	....	....	
26.1	7	Dec. 3	....	....	....	....	....	....	....	....	....	Killed by freeze of Dec. 24 (13° F.)
27.1	6	Dec. 9	....	....	....	....	....	....	....	....	....	" " "
28.1	7	Dec. 18	....	....	....	....	....	....	....	....	....	" " "
29.2	10	Dec 30	1907 Jan. 3	1907 Feb. 6	....	....	....	No hatch.	....	....	....	
29.3	10	Dec. 30	....	....	....	....	....	....	....	....	....	Killed by freezing. On Bermuda sod.
31.1	10	1907 Jan. 11	1907 Jan. 15	1907 Feb. 6	....	....	....	No hatch	....	....	....	
31.22	3	Jan. 11	Jan. 15	Feb. 15	31	M.	137	1907 June 1	1907 July 29	58	199	In laboratory until Feb. 19, then outdoors
32.1	10	Jan. 22	....	....	....	....	....	....	....	....	....	Killed by freeze of Jan. 28 (15° F.)
33.1	5	Jan. 28	1907 Mar. 20	1907 April 9	20	M.	....	No hatch.	....	....	....	
34.1	5	Feb. 8	Mar. 17	May 4	48	M.	100	1907 June 25	1907 Oct. 24	121	258	
35.11	4	Feb. 16	Mar. 15	May 8	54	D.	103	June 26	Sept. 10	76	206	
35.12	4	Feb. 16	Mar. 14	April 10	27	M.	104	June 26	Oct. 4	100	230	
35.4	48	Feb. 16	Mar. 15	April 11	27	M.	75	May 29	Aug. 3	66	168	
36.21	6	Feb. 24	Mar. 15	May 12	58	M.	101	June 24	Sept. 10	78	198	
36.22	6	Feb. 24	Mar. 15	April 30	46	D.	101	June 24	Oct. 4	102	222	
37.21	11	Mar. 20	Mar. 25	May 13	49	M.	72	June 5	Oct. 24	141	218	
37.22	9	Mar. 20	Mar. 25	May 9	45	D.	64	May 28	Oct. 8	133	202	
38.21	8	Mar. 26	April 5	May 13	38	D.	74	June 18	Oct. 17	121	205	
38.22	9	Mar. 26	April 4	May 16	42	M.	72	June 15	Oct. 4	111	192	
39.1	7	April 3	April 22	May 13	21	M.	66	June 27	Oct. 24	119	204	
43.31	4	May 17	May 21	June 26	36	M.	50	July 10	1908 Jan. 18	192	246	
43.32	3	May 17	May 21	June 23	33	D.	50	July 10	1907 Oct. 24	106	160	
44.1	12	May 23	June 4	July 4	30	M.	43	July 17	1908 Jan. 18	185	240	
44.2	14	May 23	May 31	July 2	32	D.	47	July 17	1907 Nov. 2	108	163	
45.31	10	May 29	June 9	July 3	24	M.	38	July 17	1908 Feb. 7	205	254	
45.32	10	May 29	June 9	July 3	24	D.	38	July 17	Feb. 25	223	272	
47.21	6	June 12	June 16	July 5	19	M.	33	July 19	Jan. 18	183	220	
47.22	6	June 12	June 15	July 8	23	D.	36	July 21	Feb. 25	219	258	

TABLE XIII—*Continued*

Sub-No.	No. of ticks	Date of collection	Oviposition period: Began laying	Oviposition period: Ceased laying	Oviposition period: Da's	Moist or dry	Incubation period	Seed-tick stage: Hatching	Seed-tick stage: Dead	Seed-tick stage: Days	Total days	Remarks
49.21	22	1907 June 19	1907 June 23	1907 July 9	16	D.	28	1907 July 21	1908 Jan. 15	178	210	
49.22	21	June 19	June 23	July 9	16	M.	28	July 21	Jan. 20	183	215	
50.31	2	June 25	June 28	July 14	16	D.	29	July 27	Apr. 4	252	284	
50.32	2	June 25	June 28	July 13	15	M.	29	July 27	Apr. 30	278	310	
51.21	2	July 3	July 7	July 18	11	M.	26	Aug. 2	Mar. 5	216	245	
51.22	2	July 3	July 7	July 16	9	D.	30	Aug. 6	Feb. 7	185	218	
52.21	6	July 12	July 14	July 28	14	M.	29	Aug. 12	Apr. 4	236	267	
52.22	6	July 12	July 14	July 30	16	D.	27	Aug. 10	Apr. 16	250	279	
53.21	4	July 17	July 20	Aug. 4	15	M.	34	Aug. 23	May 6	257	294	
53.22	3	July 17	July 20	Aug. 5	16	D.	34	Aug. 23	May 28	279	316	
55.21	3	July 30	Aug. 2	Aug. 19	17	D.	33	Sept. 4	May 6	245	282	
55.22	4	July 30	Aug. 2	Aug. 19	17	M.	34	Sept. 5	June 20	289	327	
56.21	8	Aug. 7	Aug. 10	Aug. 28	18	D.	35	Sept. 14	May 27	256	294	
56.22	8	Aug. 7	Aug. 10	Aug. 26	16	M.	35	Sept. 14	May 28	257	295	
59.21	12	Aug. 17	Aug. 20	Sept. 10	21	M.	40	Sept. 29	June 20	265	308	
59.33	37	Aug. 17	Aug. 18	Sept. 6	19	M.	31	Sept. 18	July 9	295	327	In laboratory until end of oviposition, then outdoors.
59.34	37	Aug 17	Aug. 18	Sept. 6	19	D.	31	Sept. 18	June 10	266	298	
60.1	10	Aug. 21	Aug. 24	Sept. 10	17	M.	36	Sept. 29	July 9	284	323	
60.2	10	Aug. 21	Aug. 24	Sept. 10	17	D.	37	Sept. 30	June 10	254	294	
61.11	3	Aug. 28	Aug. 31	Sept. 15	15	M.	198	1908 Mar. 16	June 20	96	297	
61.12	2	Aug. 28	Aug. 31	Sept. 18	18	D.	72	1907 Nov. 11	?	....	....	Only a few seed ticks
62.11	7	Aug. 29	Sept. 1	Sept. 23	22	M.	197	1908 Mar. 16	June 20	96	296	
62.12	6	Aug. 29	Sept. 1	Sept. 25	24	D.	....	No hatch	....	....	....	
63.11	3	Sept. 4	Sept. 8	Sept. 28	20	M.	219	Apr. 14	July 15	92	315	
63.12	3	Sept. 4	Sept. 8	Oct. 1	23	D.	....	No hatch	....	....	....	
64.11	3	Sept. 11	Sept. 14	Oct. 10	26	M.	219	Apr. 20	Sept. 6	139	361	
64.12	3	Sept. 11	Sept. 14	Oct. 8	24	D.	....	No hatch	....	....	....	
65.11	3	Sept. 18	Sept. 23	Oct. 10	17	M.	232	May 12	Aug. 7	87	324	
65.12	3	Sept. 18	Sept. 22	Oct. 10	18	D.	....	No hatch	....	....	....	
66.22	3	Sept. 23	Sept. 28	Nov. 5	38	M.	231	May 16	Aug. 20	96	332	
66.23	3	Sept. 23	Sept. 29	Oct. 31	32	D.	....	No hatch	....	....	....	
68.21	3	Oct. 2	Oct. 7	Nov. 11	35	M.	226	May 20	July 29	70	301	
68.22	4	Oct. 2	Oct. 7	Nov. 11	35	D.	....	No hatch	....	....	....	
69.11	6	Oct. 9	Oct. 21	Nov. 24	34	M.	....	"	....	....	....	
69.12	3	Oct. 9	Oct. 21	Nov. 24	34	D.	....	"	....	....	....	
70.11	3	Oct. 16	Oct. 25	Nov. 24	30	M.	....	"	....	....	....	
70.12	4	Oct. 16	Oct. 20	Nov. 24	35	D.	....	"	....	....	....	
71.11	3	Oct. 23	Oct. 27	Dec. 5	39	M.	....	"	....	....	....	Adult ticks killed by freeze of Dec. 5

71.12	4	1907 Oct. 23	1907 Oct. 27	1907 Dec. 5	39	D.	....	No hatch	....	....	....	Adult ticks killed by freeze of Dec. 5
72.1	7	Nov. 13	....	....	....	....	....	....	....	....	....	Killed by freeze of Dec. 5
73.1	7	Nov. 20	....	....	....	....	....	....	....	....	....	" "
74.1	3	Dec. 5	....	....	....	....	....	....	....	....	....	" "
74.2	2	Dec. 5	....	....	....	....	....	....	....	....	....	" "
76.2	3	Dec. 26	....	....	....	....	....	....	....	....	....	Killed by freeze of Jan. 23, (17° F.)
77.2	4	Dec. 31	....	....	....	....	....	....	....	....	....	" " " "
78.	2	1908 Jan. 1	....	....	....	....	....	....	....	....	....	" " " "
79.1	3	Jan. 8	....	....	....	....	....	....	....	....	....	" " " "
80.1	5	Jan. 15	....	....	....	....	....	....	....	....	....	" " " "
81.2	2	Jan. 22	....	....	....	....	....	....	....	....	....	" " Feb. 2, (14° F.) Ticks buried in chaff
81.3	2	Jan. 22	....	....	....	....	....	....	....	....	....	" " " Ticks buried in chaff
81.4	2	Jan. 22	....	....	....	....	....	....	....	....	....	" " "
82.1	2	Jan. 29	....	....	....	....	....	....	....	....	....	" " Feb. 20
83.1	2	Feb. 5	....	....	....	....	....	....	....	....	....	" " "
83.2	4	Feb. 5	....	....	....	....	....	....	....	....	....	" . "
84.2	3	Feb. 14	....	....	....	....	....	....	....	....	....	" " .
86.11	2	Feb. 19	1908 Mar. 6	1908 Apr. 29	54	M.	90	1908 June 4	1908 Oct. 4	125	231	
86.12	1	Feb. 19	Mar. 17	Apr. 25	39	D.	77	June 2	Sept. 12	102	206	
87.11	3	Feb. 26	Mar. 6	Apr. 18	43	M.	85	May 30	Aug. 30	92	186	
87.12	3	Feb. 26	Mar. 8	Apr. 26	49	D.	82	May 29	Sept. 12	106	199	
88.21	2	Mar. 4	Mar. 8	Apr. 28	51	M.	83	May 30	Aug. 30	92	179	
88.22	2	Mar. 4	Mar. 15	Apr. 25	41	D.	81	June 4	Oct. 5	123	215	
90.11	3	Mar. 25	Mar. 31	May 4	34	M.	64	June 3	Nov. 7	157	227	
90.12	2	Mar. 25	Mar. 29	Apr. 30	32	D.	64	June 1	Sept. 13	104	172	
91.11	7	Apr. 1	Apr. 7	May 15	38	M.	57	June 3	Nov. 5	155	218	
91.12	6	Apr. 1	Apr. 6	May 10	40	D.	58	June 3	Nov. 1	151	214	
92.11	4	Apr. 9	Apr. 14	May 16	32	M.	57	June 10	Nov. 5	148	210	
92.12	3	Apr. 9	Apr. 14	May 17	33	D.	58	June 11	Nov. 28	170	233	
92.13	4	Apr. 9	....	....	....	M.	....	June 12	Nov. 14	94	158	Adult females less than half engorged
94.1	4	May 15	May 19	June 5	17	M.	32	June 20	1909 Jan. 1	195	231	
94.2	4	May 15	May 19	June 5	17	D.	33	June 21	1908 Dec. 1	163	200	
95.1	7	May 20	May 22	June 7	16	M.	33	June 24	1909 Feb. 10	231	266	Last seed ticks killed by freeze of Feb. 10
95.2	6	May 20	May 22	June 7	16	D.	33	June 24	1908 Nov. 18	147	182	
96.1	3	May 28	June 1	June 25	24	M.	36	July 7	1909 Feb. 10	218	258	Last seed ticks killed by freeze of Feb. 10
96.2	3	May 28	June 1	June 15	14	D.	36	July 7	Jan. 20	197	237	
97.1	8	June 3	June 15	June 26	11	M.	22	July 7	Feb. 10	218	252	Last seed ticks killed by freeze of Feb. 10
97.2	8	June 3	June 15	June 24	9	D.	22	July 7	Feb. 10	218	252	" " " " "
98.1	6	June 10	June 15	June 29	14	M.	28	July 13	Feb. 10	212	245	" " " " "
98.2	6	June 10	June 15	June 29	14	D.	28	July 13	Feb. 10	212	245	" " " " "
99.1	8	June 24	June 28	July 9	11	M.	26	July 25	Feb. 10	201	231	" " " " "
99.2	8	June 24	June 28	July 9	11	D.	26	July 25	Feb. 10	201	231	" " " " "
100.1	7	July 1	July 4	July 19	15	M.	31	Aug. 4	Apr. 15	254	288	

TABLE XIII—*Continued*

Sub-No.	No. of ticks	Date of collection	Oviposition period			Moist or dry	Incubation period	Seed-tick stage			Total days	Remarks
			Began laying	Ceased laying	Da's			Hatching	Dead	D'ys		
100.2	6	1908 July 1	1908 July 4	1908 July 19	15	D.	31	1908 Aug. 4	1909 Feb. 10	190	224	Last seed ticks killed by freeze of Feb. 10
101.1	7	July 8	July 11	July 27	16	M.	29	Aug. 9	Apr. 20	254	286	
101.2	7	July 8	July 11	July 27	16	D.	30	Aug. 10	Apr. 2	235	268	
102.1	4	July 15	July 17	July 30	13	M.	30	Aug. 16	June 10	298	330	
102.2	3	July 15	July 17	July 30	13	D	30	Aug. 16	Apr. 15	242	274	
103.1	6	July 22	July 25	Aug. 5	12	M.	53	Sept. 15	May 10	237	293	
103.2	5	July 22	July 25	Aug. 8	15	D.	53	Sept. 15	Feb. 10	148	204	Last seed ticks killed by freeze of Feb. 10
104.1	4	Aug. 6	Aug. 7	Aug. 20	13	M.	30	Sept. 6	June 15	282	313	
104.2	4	Aug. 6	Aug. 7	Aug. 20	13	D.	36	Sept. 12	Apr. 15	215	252	
105.1	7	Aug. 6	Aug. 13	Sept. 2	20	M.	39	Sept. 21	July 3	285	326	
105.2	6	Aug. 11	Aug. 13	Aug. 31	18	D.	40	Sept. 22	Apr. 10	200	242	
106.1	4	Aug. 18	Aug. 21	Sept. 10	20	M.	48	Oct. 8	June 25	260	311	
106.2	4	Aug. 18	Aug. 21	Sept. 10	20	D.	48	Oct. 8	Apr. 10	184	235	
108.1	7	Aug. 25	Aug. 27	Sept. 18	22	M.	73	Nov. 8	June 20	224	299	
108.2	6	Aug. 25	Aug. 27	Sept. 18	22	D.	76	Nov. 11	Jan. 31	81	159	Last seed ticks killed by freeze of Jan. 31 (8° F.
109.1	5	Aug. 31	Sept. 4	Spet. 24	20	M.	183	1909 Mar. 6	June 10	96	293	
109.2	10	Aug. 31	Sept. 4	Sept. 24	20	D.	....	No hatch	....	....	....	
110.1	13	Sept. 7	Sept. 9	Sept. 30	21	M.	234	1909 May 1	July 20	80	316	
110.2	14	Sept. 7	Sept. 9	Sept. 28	19	D.	....	No hatch	....	....	....	
111.1	3	Sept. 18	Sept. 22	Nov. 3	42	M.	242	1909 May 22	Sept. 5	106	352	
111.2	3	Sept. 18	Sept. 22	Nov. 1	40	D.	....	No hatch	....	....	....	
112.1	6	Sept. 21	Sept. 24	Nov. 10	47	M.	240	1909 May 22	Aug. 30	100	343	
112.2	6	Sept. 21	Sept. 24	Nov. 9	46	D.	....	No hatch	....	....	....	
113.1	8	Sept. 28	Oct. 9	Nov. 27	49	M.	235	1909 June 1	Sept. 2	93	339	
113.2	8	Sept. 28	Oct. 9	Nov. 25	47	D.	....	No hatch	....	....	....	
114.1	6	Oct. 5	Oct. 9	Dec. 12	64	M.	233	1909 May 30	Sept. 1	94	331	
114.2	6	Oct. 5	Oct. 9	Nov. 27	49	D.	....	No hatch	....	....	....	
115.11	9	Oct. 12	Oct. 18	Jan 1	75	M.	243	1909 June 18	Aug. 10	53	301	
115.12	8	Oct. 12	Oct. 18	Jan. 6	80	D.	....	No hatch	....	....	....	
115.22	25	Oct. 12	Oct. 21	Dec. 11	51	M.	....	"	....	....	....	Adult ticks half engorged
115.23	24	Oct. 12	Oct. 21	Dec. 11	51	D.	....	"	....	....	....	" " " "
115.31	15	Oct. 12	Oct. 21	Dec. 8	48	M.	....	"	....	....	....	" " " "
115.32	15	Oct. 12	Oct. 21	Dec. 8	48	D.	....	"	....	....	....	" " " "
116.11	5	Oct. 19	Oct. 28	Dec. 25	58	M.	....	"	....	....	....	
116.12	4	Oct. 19	Oct. 28	Dec. 25	58	D.	....	"	....	....	....	
116.21	15	Oct. 19	Oct. 29	Dec. 20	52	M.	....	"	....	....	....	Adult ticks half engorged
116.22	15	Oct. 19	Oct. 29	Dec. 20	52	D.	....	"	....	....	....	" " " "
116.31	15	Oct. 19	Nov. 2	Dec. 12	40	M.	....	"	....	....	....	" " " "
116.32	15	Oct. 19	Nov. 2	Dec. 12	40	D.	....	"	....	....	....	" " " "

117.11	11	1908 Oct. 26	1908 Nov. 8	1908 Dec. 25	47	M.	....	No hatch	....	....	....	
117.12	10	Oct. 26	Nov. 10	Dec. 18	38	D.	....	"	....	....	....	
118.11	12	Nov. 3	Nov. 20	1909 Jan. 1	42	M.	....	"	....	....	....	
118.12	12	Nov. 3	Nov. 20	Jan. 6	48	D.	....	"	....	....	....	
118.21	22	Nov. 3	Nov. 26	Jan. 23	58	M.	....	"	....	....	....	Ticks but half engorged
118.22	11	Nov. 3	Nov. 26	Jan. 23	58	D.	....	"	....	....	....	" " "
118.31	31	Nov. 3	Nov. 26	Jan. 23	58	M.	....	"	....	....	....	" " "
118.32	32	Nov 3	Nov. 20	Jan. 6	48	D.	....	"	....	....	....	
119.1	4	Nov. 9	Nov. 19	Jan. 1	42	M.	....	"	....	....	....	
119.2	4	Nov. 9	Nov. 25	Jan 6	42	D.	....	"	....	....	....	
120.11	5	Nov. 16	Nov. 24	....	....	....	....	"	....	....	....	
120.12	5	Nov. 16	Nov. 24	....	....	....	....	"	....	....	....	
122.1	6	Nov. 23	Dec. 6	....	....	....	....	"	....	....	....	Killed by freeze of Dec. 3 and Jan. 31
122.2	6	Nov. 23	Dec. 6	....	....	....	....	"	....	....	....	" " " " "
124.	6	Nov. 30	1909 Jan. 25	....	....	....	....	"	....	....	....	" " " " "
125.	6	Dec. 7	Jan. 10	....	....	....	....	"	....	....	....	Killed by freeze of Jan. 31
126.	6	Dec. 14	Jan. 25	....	....	....	....	"	....	....	....	" " "
127.	8	Dec. 21	Jan. 25	....	....	....	....	"	....	....	....	" " "
128.	5	Dec. 28	Jan. 23	....	....	....	....	"	....	....	....	" " "
129.	15	1909 Jan. 4	Jan. 25	....	....	....	....	"	....	....	....	" " "
130.	6	Jan. 11	....	....	....	....	....	....	....	....	....	" " "
131.	13	Jan. 18	....	....	....	....	....	....	....	....	....	" " "
132.	12	Jan. 25	....	....	....	....	....	....	....	....	....	" " "
133.1	10	Feb. 1	Feb. 19	May 22	92	M.	107	1909 June 6	1909 Oct. 15	131	256	
133.2	9	Feb. 1	Feb. 19	May 15	85	D.	110	June 9	Oct. 15	128	256	
134.1	4	Feb. 9	Mar. 4	May 13	70	M.	98	June 10	Oct. 15	127	248	
134.2	3	Feb. 9	Feb. 22	May 18	75	D.	110	June 12	Nov. 1	142	265	
135.1	3	Feb. 15	Mar. 20	May 6	47	M.	92	June 20	Sept. 30	102	227	Adult ticks but half engorged
135.2	3	Feb. 15	Mar. 20	May 10	51	D.	....	No hatch	....	....	....	
136.01	6	Feb. 23	Mar. 19	May 22	64	M.	85	June 12	Nov. 15	156	266	
136.02	5	Feb. 23	Mar. 25	May 23	59	D.	79	June 12	Dec. 30	201	311	
136.11	4	Feb. 23	Mar. 25	May 23	61	M.	82	June 15	Oct. 10	117	230	
136.12	4	Feb. 23	Mar. 25	May 24	62	D.	82	June 15	Dec. 30	198	311	
137.1	12	Mar. 2	Mar. 20	May 12	53	M.	82	June 10	Oct. 10	122	222	
137.2	11	Mar. 2	Mar. 20	May 15	56	D.	84	June 12	Sept. 1	81	183	
138.1	3	Mar. 9	Apr. 1	May 10	39	M.	72	June 12	Oct. 10	120	215	
138.2	2	Mar. 9	Apr. 1	May 15	44	D.	70	June 10	Nov. 12	155	248	
139.1	4	Mar. 15	Apr. 1	May 18	47	M.	70	June 10	Dec. 30	203	290	Seed ticks killed by freeze of Dec. 30 (4° F.)
139.2	4	Mar. 15	Apr. 1	May 18	47	D.	69	June 9	Nov. 10	154	240	
140.1	3	Mar. 22	Apr. 4	May 10	36	M.	69	June 12	Oct. 5	103	185	
140.2	3	Mar. 22	Apr. 4	May 15	41	D.	69	June 12	Dec. 30	201	283	Seed ticks killed by freeze of Dec. 30 (4° F.)
142.1	10	Apr. 5	Apr. 14	May 22	39	M.	57	June 10	Dec. 30	203	269	Seed ticks killed by freeze of Dec. 30 (4° F.)
142.2	9	Apr. 5	Apr. 14	May 22	39	D.	57	June 10	Nov. 20	163	229	
143.1	13	Apr. 28	Apr. 30	May 28	28	M.	49	June 18	Nov. 21	156	205	
143.2	13	Apr. 28	Apr. 30	May 28	28	D.	51	June 20	Nov. 20	153	204	

TABLE XIII—*Continued*

Sub-No.	No. of ticks	Date of collection	Oviposition period: Began laying	Oviposition period: Ceased laying	Oviposition period: Da's	Moist or dry	Incubation period	Seed-tick stage: Hatching	Seed-tick stage: Dead	Seed-tick stage: Da's	Total days	Remarks
144.1	3	1909 Apr. 28	1909 Apr. 30	1909 May 23	23	M.	46	1909 June 15	1909 Dec. 30	198	244	Seed ticks killed by freeze of Dec. 30 (4° F.)
144.2	3	Apr. 28	Apr. 30	May 26	26	D.	50	June 19	Nov. 25	159	209	
145.1	10	May 10	May 15	June 12	28	M.	42	June 26	Dec. 30	201	248	Seed ticks killed by freeze of Dec. 30 (4° F.)
145.2	9	May 10	May 15	June 12	28	D.	43	June 27	Dec. 30	200	248	" " " "
146.	35	May 19	May 22	June 5	14	....	38	June 29	Dec. 30	184	234	" " " "
146.1	12	May 19	May 20	June 12	23	M.	40	June 29	Dec. 30	184	224	" " " "
146.2	11	May 19	May 20	June 13	24	D.	39	June 28	Dec. 30	183	224	" " " "
147.1	20	May 24	May 27	June 18	22	M.	35	July 1	Dec. 30	182	221	" " " "
147.2	19	May 24	May 27	June 16	20	D.	37	July 1	Dec. 30	182	221	" " " "
148.1	6	June 14	June 18	July 4	16	M.	31	July 19	Dec. 30	164	199	" " " "
148.2	6	June 14	June 18	July 5	17	D.	31	July 19	Dec. 30	164	199	" " " "
149.1	6	June 21	June 24	July 9	15	M.	26	July 20	Dec. 30	163	192	" " " "
149.2	6	June 21	June 24	July 15	21	D.	26	July 20	Dec. 30	163	192	" " " "
150.1	49	May 31	....	....	....	M.	....	July 28	Dec. 30	155	213	" " " "
150.2	49	May 31	....	....	....	D.	....	July 28	Dec. 30	155	213	" " " "
151.1	19	June 7	....	....	....	M.	....	July 7	Nov. 22	138	168	
151.2	19	June 7	....	....	....	D.	....	July 7	Aug. 20	44	74	
152.1	6	June 29	July 1	July 25	24	M.	31	Aug. 1	Dec. 30	151	184	Seed ticks killed by freeze of Dec. 30 (4° F.)
152.2	6	June 29	July 2	July 26	24	D.	30	Aug. 1	Dec. 30	150	184	" " " "
153.1	5	July 5	July 8	July 25	17	M.	24	Aug. 1	Dec. 30	151	178	" " " "
153.2	4	July 5	July 8	July 23	15	D.	24	Aug. 1	Dec. 30	151	178	" " " "
157.1	4	July 26	July 29	Aug. 10	11	M.	31	Aug. 30	Dec. 30	122	156	" " " "
157.2	4	July 26	July 29	Aug. 10	11	D.	31	Aug. 30	Dec. 30	122	156	" " " "
159.1	4	Aug. 9	Aug. 13	Aug. 22	9	M.	23	Sept. 5	Dec. 30	116	143	" " " "
159.2	4	Aug. 9	Aug. 13	Aug. 22	9	D.	23	Sept. 5	Dec. 30	116	143	" " " "
161.1	5	Aug. 23	Aug. 24	Sept. 12	19	M.	38	Oct. 1	Dec. 30	90	129	" " " "
161.2	4	Aug. 23	Aug. 24	Sept. 12	19	D.	38	Oct. 1	Dec. 30	90	129	" " " "
162.1	5	Aug. 30	Sept. 1	Sept. 15	14	M.	70	Nov. 10	Dec. 30	50	121	" " " "
162.2	4	Aug. 30	Sept. 1	Sept. 13	12	D.	70	Nov. 10	Dec. 30	50	121	" " " "
163.1	4	Sept. 7	Sept. 11	Oct. 1	20	M.	200	1910 Apr. 20	1910 May 3	13	217	
163.2	4	Sept. 7	Sept. 11	Oct. 1	20	D.	....	No hatch	....	....	....	
164.1	5	Sept. 14	....	....	....	M.	....	1910 Apr. 26	Aug. 15	111	335	
164.2	4	Sept. 14	....	....	....	D.	....	No hatch	....	....	....	
165.1	4	Sept. 20	Sept. 23	Nov. 15	53	M.	252	1910 June 1	Sept. 10	101	356	
165.2	4	Sept. 20	Sept. 23	Nov. 15	53	D.	....	No hatch	....	....	....	
166.1	5	Sept. 27	....	....	....	M.	....	1910 June 2	Sept. 25	100	363	
166.2	5	Sept. 27	....	....	....	D.	....	No hatch	....	....	....	
167.1	5	Oct. 4	Oct. 7	Dec. 1	55	M.	181	1910 June 1	Aug. 25	185	269	
167.2	4	Oct. 4	Oct. 7	Dec. 1	55	D.	....	No hatch	....	....	....	

168.1	5	1909 Oct. 10	1909 Oct. 22	....	....	M.	....	No hatch	....	....	....	Killed by freeze of Dec. 10 (13° F.)
168.2	5	Oct. 10	Oct. 21	....	....	D.	....	"	....	....	....	" " " "
169.1	5	Oct. 18	Oct. 22	....	....	M.	....	"	....	....	....	" " " "
169.2	5	Oct. 18	Oct. 22	....	....	D.	....	"	....	....	....	" " " "
170.1	5	Oct. 26	Nov. 1	....	....	M.	....	"	....	....	....	" " " "
170.2	5	Oct. 26	Nov. 2	....	....	D.	....	"	....	....	....	" " " "
171.1	4	Nov. 1	Nov. 9	....	....	M.	....	"	....	....	....	" " " "
171.2	4	Nov. 1	Nov. 10	....	....	D.	....	"	....	....	....	" " " "
172.1	5	Nov. 8	Nov. 16	....	....	M.	....	"	....	....	....	" " " "
172.2	5	Nov. 8	Nov. 13	....	....	D.	....	"	....	....	....	" " " "
173.	14	Nov. 15	....	....	....	....	....	....	....	....	....	" " " "
175.	14	Nov. 22	....	....	....	....	....	....	....	....	....	" " " "
176.	15	Dec. 6	....	....	....	....	....	....	....	....	....	" " " "
177.	12	Dec. 13	....	....	....	....	....	....	....	....	....	" " Dec 21 (13° F.)
178.	13	1910 Jan. 10	....	....	....	....	....	....	....	....	....	" " Jan. 22
179.	10	1909 Dec. 27	....	....	....	....	....	No hatch	....	....	....	Nine killed by freeze of Jan. 7; 1 laid eggs
180.	10	1910 Jan. 17	....	....	....	....	....	....	....	....	....	" " Jan. 22
181.	12	Feb. 1	....	....	....	....	....	No hatch	....	....	....	Ten killed by freeze of Feb. 13; 2 laid eggs
182.	8	Feb. 8	....	....	....	....	....	....	....	....	....	Ten killed by freeze of Feb. 13
183.	10	Feb. 14	1910 Mar. 3	1910 Mar. 18	15	M.	103	1910 June 14	1910 Sept. 1	79	191	Eight killed by freeze of Feb. 18 (14° F.); 2 laid eggs
183.11	6	Feb. 21	Mar. 2	Mar. 18	16	M.	100	June 11	Sept. 10	91	200	
183.12	6	Feb. 21	Mar. 2	Mar. 17	15	D.	104	June 14	....	....	....	
184.1	4	Feb. 28	Mar. 18	May 8	56	M.	92	June 13	Sept. 2	81	186	
189.1	5	Mar. 21	Mar 26	Apr. 18	23	M.	80	June 14	Sept. 1	79	164	
194.1	5	Apr. 18	Apr. 29	June 4	36	M.	63	July 1	Sept. 1	71	145	
212.1	5	Aug. 1	....	....	....	M.	....	Sept. 2	1911 Apr. 1	221	243	
212.2	4	Aug. 1	....	....	....	D.	....	Sept. 2	Jan. 12	132	164	
214.1	6	Aug. 15	Aug. 18	Sept. 4	17	M.	33	Sept. 20	Apr. 15	207	243	
214.2	6	Aug. 15	Aug. 17	Sept. 5	19	D.	34	Sept. 20	Mar. 25	186	222	
215.1	8	Aug. 29	?	Sept. 18	....	M.	....	?	?	....	....	
215.2	7	Aug. 29	?	Sept. 21	....	D.	....	Oct. 10	?	....	....	
216.1	6	Sept. 5	Sept. 8	Sept. 28	20	M.	197	1911 Apr. 3	May 10	37	247	
216.2	5	Sept. 5	Sept. 8	Sept. 27	19	D.	....	No hatch	....	....	....	
217.1	8	Sept. 19	Sept. 21	Oct. 20	29	M.	228	May 7	?	....	....	
217.2	7	Sept. 19	Sept. 21	Oct. 19	28	D.	....	No hatch	....	....	....	
220.1	8	Oct. 10	Oct. 13	Oct. 19	....	M.	225	May 26	....	....	....	Adult ticks killed by freeze of Dec. 21 (17° F.)
220.2	7	Oct. 10	Oct. 13	Oct. 19	....	D.	....	No hatch	....	....	....	" " " " " " "
221.1	12	Oct. 17	Oct. 20	....	....	M.	....	"	....	....	....	" " " " " " "
221.2	13	Oct. 17	Oct. 21	....	....	D.	....	"	....	....	....	" " " " " " "
222.	16	Oct. 24	....	....	....	....	....	....	....	....	....	" " " " " " "
223.	15	Oct. 31	....	....	....	....	....	....	....	....	....	" " " " " " "
224.	12	Nov. 7	....	....	....	....	....	....	....	....	....	" " " " " " "
225.	12	Nov. 14	....	....	....	....	....	....	....	....	....	" " " " " " "
226.	12	Nov. 21	....	....	....	....	....	....	....	....	....	" " " " " " "
227.	6	Nov. 28	....	....	....	....	....	....	....	....	....	" " " " " " "

TABLE XIII—*Continued*

Sub-No.	No. of ticks	Date of collection	Oviposition period			Moist or dry	Incubation period	Seed-tick stage			Total days	Remarks
			Began laying	Ceased laying	Da's			Hatching	Dead	Da's		
229.	10	1910 Dec. 12	....	....	....	....	....	....	....	....	....	Adult ticks killed by freeze of Dec. 21 (17° F.)
230.	10	Dec. 19	....	....	....	....	....	....	....	....	....	" " " " Jan. 4 (13° F.)
231.	10	Dec. 26	....	....	....	....	....	....	....	....	....	" " " " " "
232.1	5	1911 Jan. 2	....	....	....	....	....	....	....	....	....	" " " " Jan. 5 (14° F.)
232.2	5	Jan. 2	....	....	....	....	....	....	....	....	....	" " " Feb. 22; under chaff —wet
233.	10	Jan. 9	1911 Jan. 11	1911 May 13	122	M.	....	No hatch	....	....	....	Seven killed by freeze of Feb. 22; 2 laid eggs
234.	16	Jan. 23	Feb. 16	May 20	93	M.	....	"	....	....	....	Six killed by freeze of Feb. 22; 10 laid eggs
235.	12	Jan. 30	Feb. 11	?	....	M.	....	"	....	....	....	Seven killed by freeze of Feb. 22; 5 laid a few eggs

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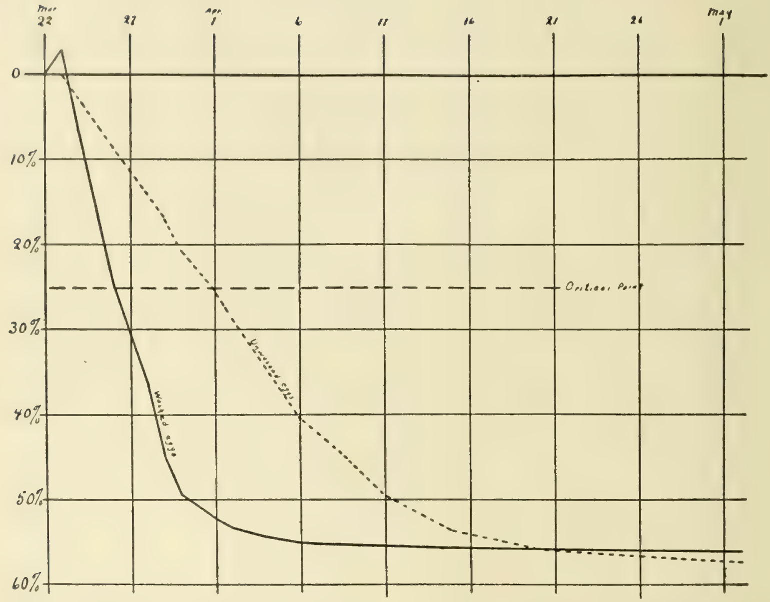

FIG. 1—CURVES SHOWING RATE OF LOSS OF WATER FROM WASHED AND UNWASHED EGGS

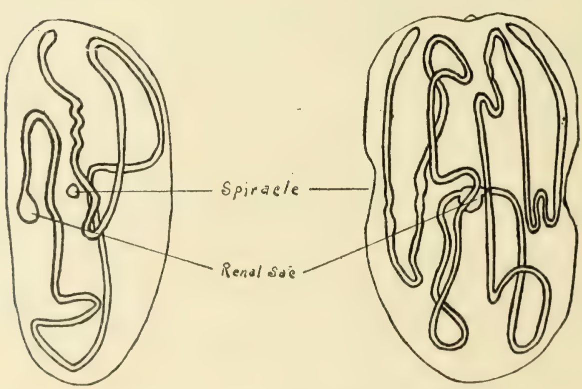

FIG. 2—SCHEMA SHOWING COURSE OF MALPIGHIAN TUBES *in situ* IN BODY OF FULLY ENGORGED FEMALE, BLEACHED ENTIRE WITH HYDROGEN PEROXID

FIG. 3—ADULT, NEARLY SPENT, FEMALE TICK WITH EGG MASS (X4)

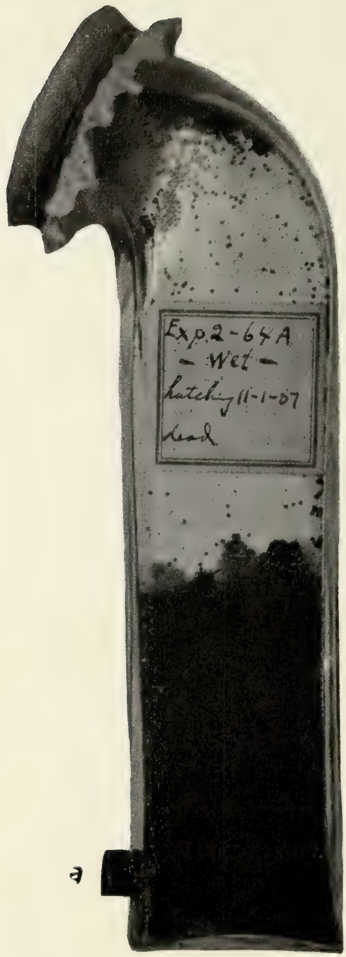

FIG. 4—BENT-NECK BOTTLE FOR REARING SEED TICKS ON MOIST AND DRY SAND

a—Irrigating opening.

FIG. 5—MALPIGHIAN TUBES AND RENAL SAC DISSECTED FROM FRESH SPECIMEN, SHOWING RELATION TO ALIMENTARY TRACT

a—Esophagus

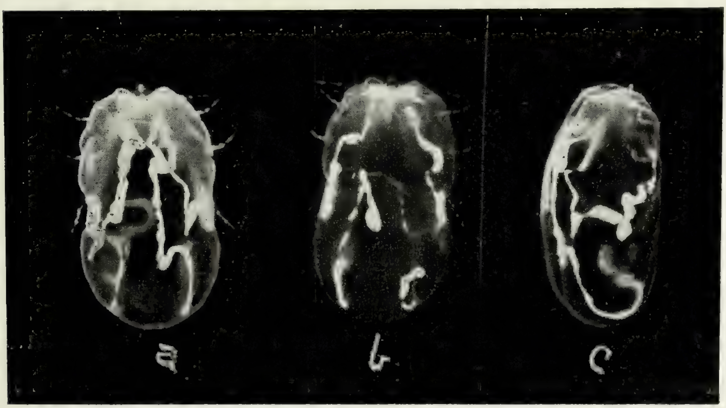

FIG. 6—MALPIGHIAN TUBES *in situ* IN ENGORGED FEMALE, BLEACHED ENTIRE WITH HYDROGEN PEROXID AND CLEARED IN XYLOL (X4)

a—Dorsal view; b—Ventral view; c—Lateral view.

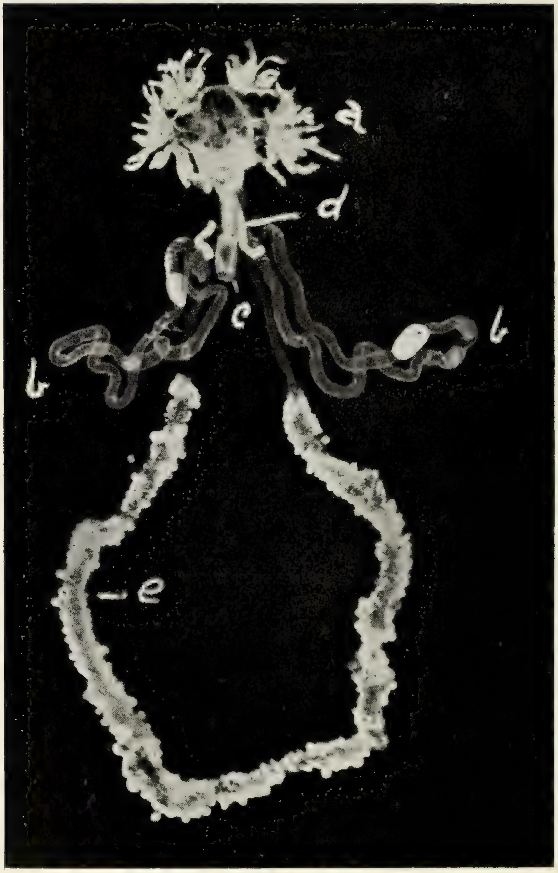

FIG. 7—REPRODUCTIVE SYSTEM OF ENGORGED FEMALE BEFORE OVIPOSITION, DISSECTED FROM FRESH SPECIMEN

a—Shell glands; b—Oviducts; c—Seminal receptacle; d—Accessory glands; e—Ovary.

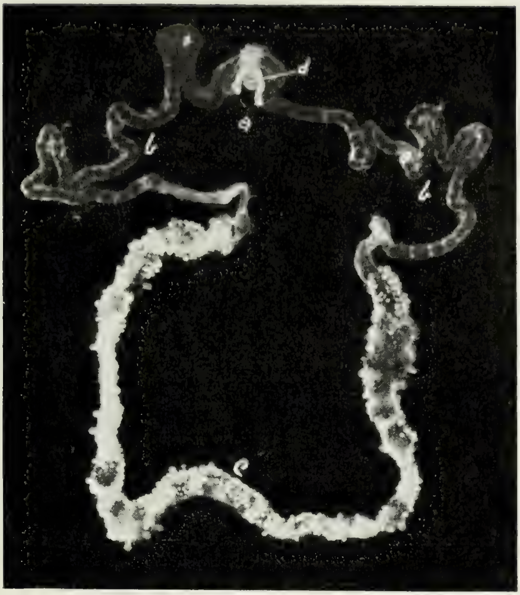

FIG. 8—REPRODUCTIVE SYSTEM OF NEARLY SPENT FEMALE
a—Accessory glands; b—Oviducts; c—Ovary; d—Seminal receptacle.

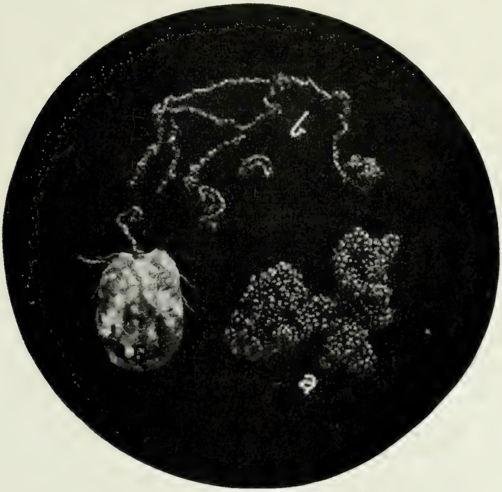

FIG. 9—NEARLY SPENT FEMALE WITH EGGS (X3)
a—Normal eggs laid before exposure of ovipositing tick to cold; b—Strings of eggs laid after the shell glands had been injured by cold—all eggs laid by same tick.

FIG. 10—TICK EGGS

a—Coated eggs plump and fresh after long exposure; b—Uncoated eggs shrunken from loss of moisture.

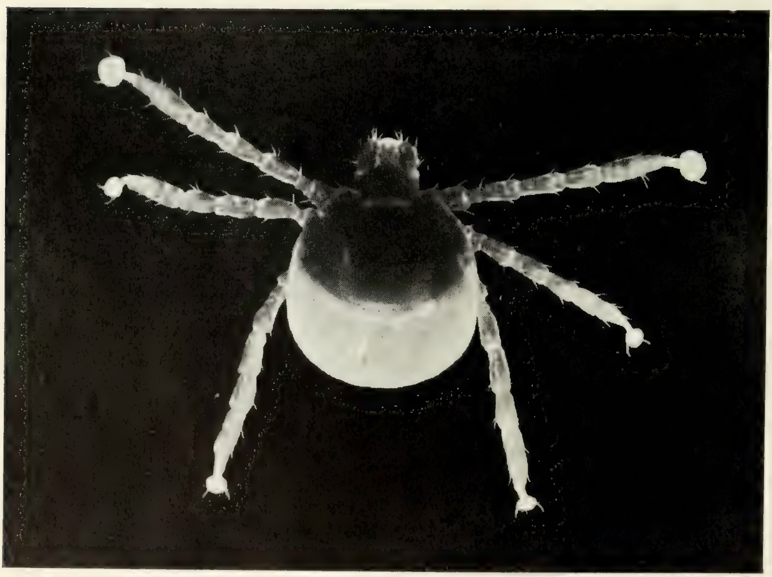

FIG. 11—SEED TICK

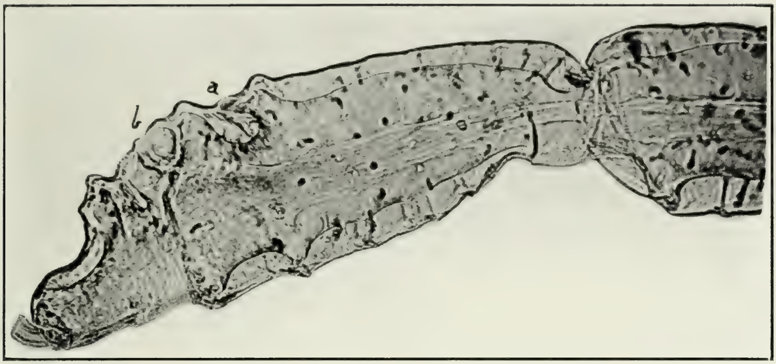

FIG. 12—TARSUS OF LEG I OF ADULT FEMALE (*Amblyomma cajennense*) BLEACHED WITH HYDROGEN PEROXID, SHOWING HALLER'S ORGAN (X128)
a—Sensory pit; b—Accessory pit.

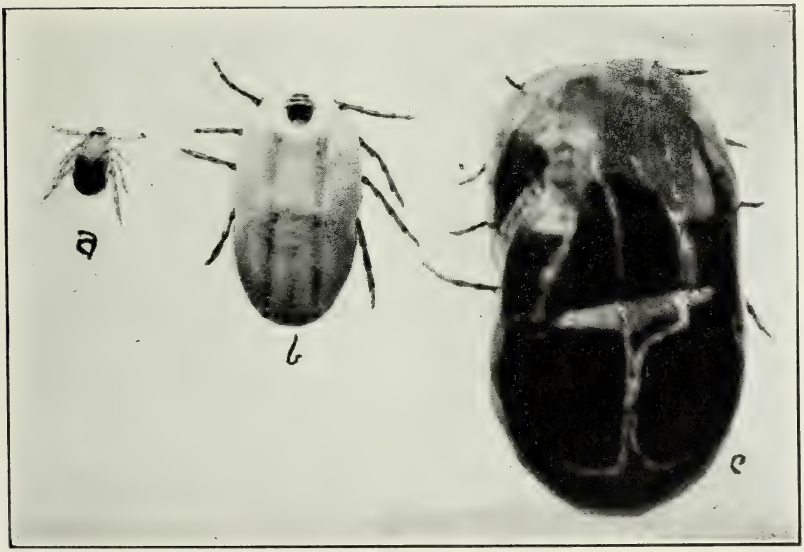

FIG 13—NYMPH AND ADULT FEMALE (X5)
a—Newly molted nymph; b—Adult female just after beginning of engorgement; c—Fully engorged female.

FIG. 14—ALIMENTARY TRACT OF ENGORGED FEMALE, DISSECTED UNDER WATER FROM FRESH SPECIMEN

a—Esophagus; b—Renal sac showing attachment of Malpighian tubes.

FIG. 15—LATERAL VIEW OF ENGORGED FEMALE, SHOWING RADIATION OF TRACHEAL TRUNKS FROM THE STIGMA THROUGH THE PARTLY BLEACHED CUTICLE (X4.6)

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RELATION OF STEER FEEDING TO FARM RETURNS

By
C. A. WILLSON

STEERS USED IN EXPERIMENT

KNOXVILLE, TENNESSEE

The Agricultural Experiment Station

OF THE UNIVERSITY OF TENNESSEE

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The Experiment Station building, containing the offices and laboratories, and the plant house, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy building, etc., are located one mile west of the University on the Kingston Pike. The fruit farm is adjacent to the Industrial School and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State

SUMMARY

1. Soy beans and barley ranked ahead of all other combinations used in these experiments in the amount of food material produced per acre. Page 103.

2. Soy beans ranked ahead of cowpeas in the production of grain each year. Page 103.

3. Better results can be secured from soy beans and barley as a rotation for the production of beef than from any other combination of crops used in these experiments. Page 105.

4. The rotation in which soy beans were used produced an average of 57 pounds more beef per acre than that in which cowpeas were used, and 74 pounds more than that in which corn was used. Page 105.

5. Larger beef gains were obtained per acre when the soy beans were allowed to reach maturity than when they were made into hay. Page 105.

6. Acre I, soy beans and barley, produced an average of 70 pounds more beef than Acre IV, soy beans, hay and barley. Page 105.

7. The soy-bean grain and barley acre ranked ahead of all the other rotations in the gross returns of beef per acre. This rotation produced an average of $61.23 per acre. Page 108.

8. The average gross returns per acre for each of the acres were as follows: Soy-bean grain and barley, $61.23; cowpea grain and barley, $58.94; corn and barley, $56.92; soy-bean hay and barley, $57.07; soy-bean grain and wheat, $55.99; soy-bean hay and oats, $59.23; alfalfa, $58.91. Page 108.

9. The average gross returns for beef sold from all the acres on experiment was $58.34, and the average beef yield for all the acres on experiment was 450 pounds. Page 108.

10. The returns in beef yield were 33 per cent larger when the crops grown were fed off in 90 days than when they were fed off in 60 days. Also the steers on 90-day feed, on account of their increased finish, would likely sell at ¼ to ½ cent more per pound than the steers on 60-day feed. Page 108.

11. The average prices received for the crops marketed through the steers were as follows: Soy beans, $1.40 per bushel; cowpeas, $1.60; wheat, $1.39; oats, $.57; barley, $1.02; corn, $1.00; soy-bean hay, $17.50 per ton; alfalfa hay, $14.20. Page 110.

12. If the crops produced on each acre were sold as grain or hay and the removal from the farm of the fertilizing elements were

reckoned as a factor, the price that each grain or hay would have to sell at in order to equal the returns obtained from the marketing of these through steers would be, for soy beans, $2.05 per bushel; for cowpeas, $2.03; for wheat, $1.60; for oats, $.69; for barley, $1.21; for corn, $1.17; for soy-bean hay, $27.99 per ton; for alfalfa hay, $24.03 per ton. Page 111.

13. The pounds of beef produced per acre were much larger when the winter-grown crop was fed instead of being plowed under. Pages 87 and 104.

14. The average beef yields per acre with the single-crop method were, for Acre I, where soy beans were grown and fed, 473 pounds; for Acre II, where cowpeas were grown, 294 pounds; for Acre III, where corn was grown, 165 pounds. The average beef yield with the double-crop method where both crops were fed, were, for the barley and soy-bean acre, 508 pounds; for the barley and cowpea acre, 451 pounds; for the barley and corn acre, 434 pounds. Page 109.

15. These experiments show that excellent returns per acre can be secured on Tennessee farms through the feeding of the crops to beef steers and the fertility be retained on the farm.

RELATION OF STEER FEEDING TO FARM RETURNS

INTRODUCTION

In Bulletin 79, published by this Station in 1903, the grains produced through the feeding to steers of crops grown on the farm were related to the acre basis. The present bulletin is a continuation of that work, with such changes and additions as the preliminary work showed should be made.

The author wishes to acknowledge his indebtedness to Director H. A. Morgan for many valuable suggestions, and for personal supervision of the experiments previous to the time that the author took up the work.

STEER FEEDING IN FARM ECONOMICS

Before beginning any type of farming, one should consider whether or not it will pay. That is usually the first question asked with regard to beef production in any particular section. The question is meant to be a relative one. The inquirer wishes to know whether beef production will pay more than some other kind of agriculture that he might engage in, and what profit he may expect to make if he engage in the raising of live stock instead of selling his crops from the farm. Most of all he wishes to know how much money he may expect to have on hand when tax time comes, or when he must meet the various other expenses that necessarily arise in the running of a farm.

In order to answer such questions with regard to beef-cattle raising it is necessary to relate the work to the acre basis. A feed that is shown to be the most profitable in a feeding trial when considered on the basis of market prices may prove to be the least successful when grown in actual practice for the production of beef. There are several reasons for this. The feed that gives the highest returns in the feeding trial may produce the smallest amount of food nutrients per acre, or it may be produced at much greater expense per acre, or it may remove more food nutrients per acre, and hence necessitate larger quantities of the fertilizing elements to replace the loss. These considerations are of more importance in determining the final returns from the farm than is the question which feed will make the most beef per given quantity. The data most needed by the farmer at the present time with regard to live stock production are those that will relate the work to the acre basis. The farmer needs to know which type of farming will return the most per farm. He is interested in

the question which type of farming will return the most over a series of years, and not which will return the most for one year without regard to weather conditions or the condition that the soil will be left in at the end of the year.

Live stock increases grain production

It may be shown in some instances that the selling of the crops off the farm for one year will bring in more money than the feeding of the crops to live stock on the farm, but the history of agriculture shows that the soil is maintained in a higher state of fertility in those counties and communities where live stock production prevails. Again, live stock production is not opposed necessarily to the sale of grains and other marketable crops from the farm. Live stock on the farm will increase the crop production per acre through the conservation of soil fertility. Records of the more progressive stock farms show that they actually sell more crops than the average farm.

Live stock provides a market for cheap feeds

The chief advantage that would result from the keeping of live stock on the majority of farms is that to a large extent the returns would be additional to those realized when live stock was not kept. These returns would be additional because live stock would turn the roughages of the farms, that are now going to waste, into money. More than one-half the fodder in this State goes to waste every year. For every head of cattle in the State there are produced three acres of corn, which will average one ton of stover per acre. One and one-half ton of stover is more than is needed to winter one head of cattle. There is going to waste, then, every year in this State, 5,700,000 tons of corn stover, which at a valuation of $5.00 per ton means a loss to the farmers of the State, through a lack of proper utilization of feeds by cattle, of over $28,000,000.

Live stock conserves fertility

Beef cattle would conserve the fertility of our farms and increase our average crop production. Writers often point out to us the wonders that have been accomplished in increased crop production in the Old World countries through the utilization of crops and feeds by cattle and the return of manure to the farms, and have held up to us Denmark, Germany and other countries as marked examples of what such methods would do for our crop yields.

Example in U. S. of live stock increasing crop production

If we could find similar illustrations of what has been accomplished in our country the lesson might be more forceful. With that thought in mind, we might compare the agriculture of Tennessee with that of Wisconsin. In the year 1880 the average cereal production of Tennessee was 16.3 bushels; of Wisconsin 23.0 bushels. We should expect that it would be a little higher

in Wisconsin at that time, for Wisconsin was a new state, and Tennessee was even then becoming an old state. The average acreage of cereals was practicaly the same for the two states. The number of horses, cattle, sheep, and hogs was also practically the same. In 1910 the average cereal production of each state was as follows: Tennessee, 19.1 bushels per acre; Wisconsin, 30.4 bushels. Through better methods of agriculture the farmers of Wisconsin have increased their cereal production more than 7 bushels, while the farmers of Tennessee have increased theirs less than 3 bushels.

Certainly these differences in crop yields can be accounted for. Judging by the history of other countries, it would seem that live stock had something to do with it. A review of statistics for the year 1910 shows that the number of horses, sheep, and hogs is still practically the same for the two states, but Wisconsin farmers had 1,683,545 more cattle than Tennessee farmers. There is not much wonder, then, that Wisconsin farmers during the past thirty years have increased the production per acre of their farms by 7.4 bushels while Tennessee farmers increased theirs by only 2.8 bushels; for Wisconsin farmers are putting back on their farms $50,000,000 worth more of manure each year than are Tennessee farmers. We have been selling cottonseed meal and corn, and Wisconsin has been adding the fertility from them to her soil through the use of live stock. Wisconsin farmers keep live stock. Tennessee farmers keep practically none. The average number of cattle per farm in Wisconsin is 8.3 head. The average number of cattle per farm in Tennessee is 1.7 head. Wisconsin has five times as many cattle per farm as Tennessee, and is producing 58 per cent larger crops per acre. The increased production per acre on Wisconsin farms during the past thirty years has been 2.6 times as great as on Tennessee farms. If we are to increase the average production per acre of cereals we must follow the method of other countries and communities that have increased their crop production; that is, keep live stock.

Live stock farmers have larger incomes than grain farmers

Farmers who keep beef cattle make more money than those who depend entirely upon grain crops. In a recent investigation by the Office of Farm Management of the U. S. Department of Agriculture on live stock and grain farms in Iowa, Illinois, and Indiana, it was found that the average annual labor income of farmers who conducted live stock farms was $755, while the average annual labor income of farmers who conducted grain farms was $28. Tenants who made live stock their principal source of income had a labor income of $717, while tenants who made grain crops their principal source of income had a labor income of $327. The reason why the live stock farmers had larger labor incomes was that they utilized all the rough feeds on their farms and thus obtained a return from feeds that otherwise would have been wasted, and that they were able through the use of live stock to utilize their labor to better advantage.

The live stock farmers were also, through the use of live stock, able to sell their crops at higher prices.

There is no question that the feeding of steers by farmers of this State would result in an increase of the soil fertility and production of larger crops per acre. This means that the income of each farmer would be greater and the farmer become more prosperous.

Farm values versus market values

"Nothing else has mitigated so much against the rational relation of live stock to average farm operations as the utter disregard of the fertiltiy sold from the farm when corn and other crops are sold direct and not fed. In other words, for the sake of the soils of the State and their future production it has been altogether too common a practice for the producer to calculate the value of his crop on the market price. The market price less the fertility sold in each pound, bushel, ton, or other commercial unit is a more logical basis of estimate, and yet under any system of direct marketing of crops we lose sight of the possibility of a better price if fed to live stock on the farm, the value of the utilization of roughage, the accumulation of elements of plant food and vegetable matter in the manure, a more judicious and profitable rotation and diversity of crops, and an increasing crop yield at much less cost per acre.

"Realizing the rather unconscious effect which market values, as ordinarily interpreted, are having, and may have, upon the live stock interests, and hence upon the general agriculture of the State, the Station has undertaken a series of experiments with the view of comparing market and farm values of various Tennessee crops."

REVIEW OF PREVIOUS WORK, PUBLISHED IN BULLETIN 79

This experiment with acres of various Tennessee-grown crops was started in 1906. Three acres were planted, respectively, to soy beans, cowpeas, and corn, side by side on the Station farm. The product of each acre was fed to four steers each winter. The results for the years 1906 and 1907 were published in Bulletin 79. In those years the crops were followed by crimson clover, which was plowed under each year for green manure. Only the crop grown on the land during the summer was fed. Inasmuch as the supply of Bulletin 79 is completely exhausted, we wish to repeat in this bulletin some of the important findings of that publication, as we believe that the work done and the results obtained should be considered by the reader before the succeeding work is reviewed. Pages 86 to 95, inclusive, are extracts from that bulletin, the table numbers being adapted to the present bulletin.

The results show that in the experiment of 1906-07 the corn acre lasted the four steers 54 days, producing a gain of 129 pounds; the soy-

bean acre fed 80 days, with a gain of 406 pounds; and the cowpea acre fed 54 days, with a gain of 289 pounds. These results were so suggestive that in 1907-08 the experiment was duplicated and the results were very similar.

The yields per acre for the two years were approximately the same, viz: 34 bushels of corn and 3,544 pounds of stover; 20 bushels of soy beans and 2905 pounds of straw; 13 bushels of cowpeas and 1365 pounds of straw. The gains in this experiment were decidedly heavier than in the privious year, the gains being as follows: Corn lot, 203 pounds; soy-bean lot, 540 pounds; cowpea lot, 327 pounds. The increase in gain in this experiment over that of the previous year is accounted for by the fact that the steers were of a little better quality than those of 1906-07.

Table I shows the exact amounts eaten during the two years that the experiment was run and the average per steer per day, the total gain on the lots and the average per steer per day, the total waste, the average waste per steer per day, and the amount of gain per pound of concentrates fed. The totals in this table are used in the business statement, which covers two years.

BUSINESS STATEMENT

As has been indicated, it is one of the objects of this bulletin to call attention to the relationship between farm and market values; to show if possible the value of a farm crop when marketed in the animal or when sold on the open market, as is the too common practice. With this object in view, the following business statement is presented for the three acres planted to the respective crops:

In this statement the results of the two years' experiments are combined (see Table I); that is, the statement is made out as though eight steers were fed on the products from two acres of each of the respective crops, corn, soy beans, and cowpeas. The steers used in this experiment were in each case continued on feed after the acre experiments were concluded, and sold to the East Tennessee Packing Co., after being on full feed a total of 100 days. The steers in both experiments were purchased in East Tennessee, off grass, for 4¼ cents, were fed for 30 days on preliminary feed before going on experiment, and sold, after being on full feed 100 days, for 5 cents.

In connection with this business statement attention should be called to the fact that the selling price of the steers is not what they would have brought at the end of the acre experiments, but what they were sold for at the end of 100 days. It is manifest that it would have been impracticable to sell the steers from the corn or cowpea acre at the end of the 54-day periods for 5 cents, when it is remembered that they cost 4¼ cents as feeders in the beginning of the experiment. The soy-bean lot, however, which fed 80 days, and in the two years made an average of 118 pounds gain per steer, could have been sold at the end of the 80 days for 5 cents. When it is remembered that it

TABLE I—*Statement of feed and gains*

Four steers fed 54 days

Lot I Corn acre	Corn eaten	Av. per steer per day	Stover eaten	Av. per steer per day	Silage eaten	Av. per steer per day	Total gain	Av. gain per steer per day	Corn per lb. gain	Total waste	Av. waste per steer per day
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Dec. 8, 1906-Jan. 30, 1907	2450	11.34	1912	8.85	4320	20.00	128	0.59	19.10	1531	7.08
Dec. 2, 1907-Jan. 24, 1908	2455	11.34	1632	7.55	4400	20.37	203	0.94	12.06	1015	4.72
Total for 2 years	4905		3544		8720		331				

Four steers fed 80 days

Lot II Soy-bean acre	Soy beans eaten	Av. per steer per day	Soy-bean straw eaten	Av. per steer per day	Silage eaten	Av. per steer per day	Total gain	Av. gain per steer per day	Soy-bean meal per lb. gain	Total waste	Av. waste per steer per day
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Dec. 8, 1906-Feb. 25, 1907	1133	3.54	3585	11.2	6814	21.29	406	1.27	2.78	415	1.92
Dec. 2, 1907-Feb. 19, 1908	1184	3.70	3280	10.25	6640	20.12	540	1.68	2.19	287	1.32
Total for 2 years	2317		6865		13454		946				

Four steers fed 54 days

Lot III Cowpea acre	Cowpea meal eaten	Av. per steer per day	Cowpea straw eaten	Av. per steer per day	Silage eaten	Av. per steer per day	Total gain	Av. gain per steer per day	Cowpea meal per lb. gain	Total waste	Av. waste per steer per day
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Dec 8, 1906-Jan. 30, 1907	751	3.49	2404	11.12	4240	19.62	261	1.21	2.87	303	1.40
Dec. 2, 1907-Jan. 24, 1908	751	3.49	2200	10.18	4400	20.37	327	1.51	2.29	66	0.30
Total for 2 years	1502		4604		8640		588				

TABLE II—*Cost of production of corn acres*

	One acre	Two acres
Seed value	$ 0.21	$ 0.42
Shelling seed	0.02	0.04
Plowing	2.00	4.00
Disking	0.34	0.68
Dragging	0.48	0.96
Planting (horse planter)	0.25	0.50
Cultivating	1.62	3.24
Cutting (corn binder)	0.52	1.04
Shocking and tying	0.40	0.80
Twine	0.21	0.42
Cutting stover and grinding	3.31	6.62
Hauling to barn	1.00	2.00
Land rent	4.50	9.00
Total	$14.86	$29.72

was impossible to sell the steers on the corn and cowpea acres at the end of 54 days for the price of 5 cents used in this statement, and that at the end of 80 days the steers on the soy beans were in condition to demand 5 cents, it is clear that in expressing these calculations undue advantage has been given to both corn and cowpeas.

In table II (corn acre) is a statement of the cost of producing an acre of corn. Each item of this statement is carefully calculated from the most reliable data available, a large portion of which was gained from a cooperative experiment between the U. S. Department of Agriculture and the Minnesota Station. Minnesota Bulletin No. 97, which gives the results of the experiment, contains very reliable data on farm values, the cost of producing various crops, farm labor, worth of farm machines and cost of running same, etc. The data for this bulletin were three years in collecting and represent large averages upon all items of farm expense. The cost of production as outlined in Table II has been corrected for Tennessee conditions by comparison with the farm records of our own Station and upon the advice of practical Tennessee farmers to whom it was submitted for criticism.

In Table IV and following tables are outlined the values of the fertilizing constituents in the feeds from the respective acres which were consumed by the steers in this experiment. These values are computed from Table III, Appendix of Henry's "Feeds and Feeding." The available fertilizing compounds are placed at their standard commercial

TABLE III—*Statement of farm values—corn acres*

Dr.	Two acres of corn fed to eight steers		Cr.
Initial cost of 8 steers 7,827 lbs. at 4¼c	$332.65	8 steers, fed 54 days, sold 8,159 lbs. at 5c	$407.95
Cost of production of corn, farm value	29.72		
Labor, feeding 54 days	5.28		
15% fertilizing constituents lost in steers	5.03		
Silage, 4.36 tons at $1.82	7.93		
Bal. profit	27.34		
	$407.95		$407.95

Two acres of corn sold on the market			
Cost of production	$ 29.72	70 bu. corn at 50c	$ 35.00
Loss in fertility	26.51	1.77 ton stover at $3.00	5.31
		Bal. loss	15.92
	$ 56.23		$ 56.23

Price at which corn must be sold to balance profit and loss			
Cost of production	$ 29.72	70 bu. corn at 72.98c	$ 50.92
Loss in fertility	26.51	1.77 ton stover at $3.00	5.31
	$ 56.23		$ 56.23

TABLE IV—*Amounts and values of fertilizing constituents in feeds consumed during two years in experiment with corn acres*

Fertilizing constituent	Value per pound	4905 lbs. corn and cob meal	Fertilizing value	3544 lbs. corn stover	Fertilizing value	Total val. for corn acres	8720 pounds corn silage	Fertilizing value	Fertilizing value of all feeds
	Cts.	Lbs.		Lbs.			Lbs.		
Nitrogen	19.0	69.16	$13.14	36.85	$ 7.00	-----	24.41	$4.63	-----
Phos. acid	5.3	27.96	1.48	10.27	.54	-----	9.59	.50	-----
Potash	6.0	23.05	1.38	49.61	2.97	-----	32.26	1.93	-----
Total	---	----	$16.00	----	$10.51	$26.51	----	$7.06	$33.57

TABLE V—*Cost of production of soy-bean acres*

	One acre	Two acres
Seed value	$ 0.25	$ 0.50
Plowing	2.00	4.00
Disking	0.33	0.66
Dragging	0.48	0.96
Planting (horse planter)	0.22	0.44
Cultivating	1.61	3.22
Cutting (mowing machine)	0.60	1.20
Raking and shocking	1.50	3.00
Threshing at 6c per bushel	1.20	2.40
Grinding	0.40	0.80
Land rent	4.50	9.00
Total	$13.09	$26.18

values for Tennessee, 19 cents per pound for nitrogen, 5.3 cents for phosphoric acid, and 6 cents for potash. It is estimated that when the crop is sold on the open market all of the soil fertility contained in it is lost, and when the crop is fed to live stock and the manure returned to the land only 15 per cent is removed.

In Table III in the statement of corn fed to 8 steers the credit side shows, from the combined results of two years, that the 8 steers weighed 8,159 pounds at the end of the 54-day period, selling for 5 cents per pound, or $407.95. On the debit side is shown the initial cost of the steers at 4¼ cents when put on feed. The cost of producing an acre of corn is taken from the statement in Table II. The silage eaten is credited at farm value, or the actual cost of production. Labor in feeding and caring for the steers is placed at 66 cents each. This is the amount determined by the Illinois Station, from considerable experimental datum. Fifteen per cent of the value of the fertilizing constituents is estimated from Table IV. In Table III is a statement showing the result of selling the products from the corn acre on the market at 50 cents per bushel for the corn and $3.00 per ton for the stover. After the cost of production and the loss in fertility are deducted there is a loss of $15.92 in the transaction. The last part of the table shows that corn must sell for $0.7298 per bushel to balance profit and loss.

Tables V and VI are computed in the same way as Tables II and III. A comparison of these tables shows that the cost of the production of an acre of soy beans is slightly less than that of the corn acre.

TABLE VI—*Statement of farm values—soy-bean acres*

Dr.	Two acres of soy beans fed to eight steers		Cr.
Initial cost of 8 steers 7,595 lbs. at 4¼c	$322.78	Sold 8 steers, 8,542 lbs. at 5c	$427.10
Cost of 2 acres soy beans, farm values	26.18		
6.72 tons silage at $1.82	12.23		
Labor, feeding 80 days	7.68		
15% loss in soil fertility	10.33		
Bal. profit	47.90		
	$427.10		$427.10
	Two acres of soy beans sold on the market		
Cost of production	$ 26.18	39 bu. soy beans at $2	$ 78.00
Loss in fertility	57.96	3.43 tons soy-bean straw at $3.00	10.29
Bal. profit	4.15		
	$ 88.29		$ 88.29
	Price at which soy beans must be sold to balance profit and loss		
Cost of production	$ 26.18	39 bu. soy beans at $1.893	$ 73.85
Loss in fertility	57.96	3.43 tons soy-bean straw at $3.00	10.29
	$ 84.14		$ 84.14

TABLE VII—*Amounts and values of fertilizing constituents in feeds consumed during two years in experiment with soy-bean acres*

Fertilizing constituent	Value per pound	2317 lbs. soy-bean meal	Fertilizing value	6865 lbs. soy-bean straw	Fertilizing value	Total val. for soy-bean acres	13454 pounds corn silage	Fertilizing value	Fertilizing value of all feeds
	Cts.	Lbs.		Lbs.			Lbs.		
Nitrogen	19.0	122.80	$23.33	120.13	$22.82	-----	37.67	$ 7.15	-----
Phos. acid	5.3	43.32	2.29	27.46	1.45	-----	14.79	.78	-----
Potash	6.0	44.02	2.64	90.61	5.43	-----	49.77	2.98	-----
Total	---	-----	$28.26	-----	$29.70	$57.96	----	$10.91	$68.87

Table VI shows a balance of $47.90 profit from the soy-bean acre, or $20.56 more than from the corn acre. When the soy beans are sold on the market at $2.00 per bushel and the straw at $3.00 per ton there is a profit of $4.15, or, as shown in the last part of the table, soy beans at $1.893 per bushel will balance the profit and loss.

Table VII shows the fertilizing constituents removed in the soy beans to be worth $57.96, or $31.45 more than those removed in the corn. It will be remembered, however, that no account is taken of the fact that a large part of the nitrogen contained in the beans and peas came from the air, and the soil upon which cowpeas or soy beans are grown must in a measure be improved by the growing of these leguminous crops. While we know that there is a certain amount of improvement over the corn acre, we have not enough reliable data on the subject to give it a value or state the rate of such improvement. It is known from general observation that soils are improved by the growing of a leguminous crop and it is believed that this improvement will offset the cost of the corn silage fed in this experiment which was not produced on the acres in question.

The figures given in Tables VIII and IX for the cowpea acres are estimated in the same way as those for the corn and soy-bean acres. Table IX shows that the profit made is $39.70, or $12.36 more than the profit of the corn acre. The cost of production is about the same as for the soy-bean acre.

TABLE VIII—*Cost of production of cowpea acres*

	One acre	Two acres
Seed value	$ 0.20	$ 0.40
Plowing	2.00	4.00
Disking	0.33	0.66
Dragging	0.48	0.96
Planting (horse planter)	0.22	0.44
Cultivating	1.61	3.22
Cutting (mowing machine)	0.60	1.20
Raking and shocking	1.50	3.00
Hauling to thresher	1.60	3.20
Threshing at 9c	1.12	2.24
Grinding	0.35	0.70
Land rent	4.50	9.00
Total	$14.51	$29.02

TABLE IX—*Statement of farm values—cowpea acres*

Dr.	Acres of cowpeas fed to steers		Cr.
Initial cost of 8 steers, 7,626 lbs. at 4¼c	$324.10	Sold 8 steers, 8,242 lbs., at 5c	$412.10
Cost 2 acres cowpeas, farm values	29.02		
4.32 tons silage eaten at $1.82	7.86		
Labor, feeding 54 days	5.28		
15% loss in soil fertility	6.14		
Bal. profit	39.70		
	$412.10		$412.10

Statement when cowpeas are sold on market

Cost of production	$ 29.02	25 bu. cowpeas at $2.00	$ 50.00
Loss in fertility	33.97	2.3 tons cowpea straw at $3.00	6.90
		Bal. loss	6.09
	$ 62.99		$ 62.99

Price at which cowpeas must be sold to balance profit and loss

Cost of production	$ 29.02	25 bu. cowpeas at $2.235	$ 56.09
Loss in fertility	33.97	2.3 tons cowpea straw at $3.00	6.90
	$ 62.99		$ 62.99

TABLE X—*Amounts and values of fertilizing constituents in feeds consumed during two years in experiment with cowpea acres*

Fertilizing constituent	Value per pound	1502 lbs. cowpea meal	Fertilizing value	4600 lbs. cowpea straw	Fertilizing value	Total val. for cowpea acres	8640 pounds corn silage	Fertilizing value	Fertilizing value of all feeds
	Cts.	Lbs.		Lbs.			Lbs.		
Nitrogen	19.0	50.01	$ 9.50	89.70	$17.04	-----	24.19	$4.59	-----
Phos. acid	5.3	18.02	.95	23.92	1.26	-----	9.50	.50	-----
Potash	6.0	19.52	1.17	67.62	4.05	-----	31.97	1.92	-----
Total	---	----	$11.62	----	$22.35	$33.97	----	$7.01	$40.98

Table X shows the range of prices at which the steers might have been sold and the profit or loss that would accrue from such sales. It also shows the price per bushel at which the grain must sell on the market to produce the same profit or loss. For instance, in Table XI, corn acre, the first line shows that the 8 steers were bought for 4¼ cents per pound and weighed at time of purchase 7,827 pounds. At the end of the 54-days feed they weighed 8,159. If they had been sold at

TABLE XI—*Profit or loss when steers are sold at different prices per pound, and the price per bushel at which the feeds must sell on the market to produce a corresponding profit or loss*

Corn acres						
Bought 7,827 pounds at 4¼c., sold 8,159 pounds at	4c.	4¼c.	4½c.	4¾c.	5c.	5¼c.
Profit or loss when fed to steers	—$54.13	—$33.86	—$13.46	$ 6.94	$27.34	$47.73
Price per bushel at which corn must sell to equal the same profit or loss as above	4.47c.	24.38c.	53.51c.	82.6c.	$ 1.12	$ 1.41
Soy-bean acres						
Bought 7,595 pounds at 4¼c., sold 8,542 pounds at	4c.	4¼c.	4½c.	4¾c.	5c.	5¼c.
Profit or loss when fed to steers	—$37.52	—$16.17	$5.19	$26.54	$47.90	$69.25
Price per bushel at which soy beans must sell to equal above	98.16c.	$1.48	$2.03	$2.57	$3.12	$3.67
Cowpea acres						
Bought 7,626 pounds at 4¼c., sold 8,242 pounds at	4c.	4¼c.	4½c.	4¾c.	5c.	5¼c.
Profit or loss when fed to steers	—$42.72	—$22.12	—$1.51	$19.09	$39.70	$60.30
Price per bushel at which cowpeas must sell to equal above	53c.	$1.36	$2.18	$3.02	$3.83	$4.65

—Indicates loss.

the range of prices (4¼ to 5½ cents) indicated to the right in the same line there would be a profit or loss indicated immediately below the prices at the top of the columns at the right of the table. This second line just mentioned shows the profit or loss when the products of the acre are fed to steers according to the estimates outlined in previous tables. It is thus shown in the second column from the left (corn acre) that when steers are sold for 4¼ cents there is a loss of $33.86; when sold for 5¼ cents there is a profit of $47.73. In the line below this, or the fourth line from the top of the table, is shown the price per bushel that corn must sell for, taking into consideration the cost of production, loss in fertility, etc., as indicated in previous tables, to equal the profit or loss indicated above, when the corn is fed to steers. For instance, if steers sold for 4¼ cents there would be a loss of $33.86. If corn sold at 24.38 cents per bushel there would be an equal loss of $33.86. Similarly if the steers sold for 5¼ cents (last column) there would be a profit of $47.73; if the corn sold for $1.41 per bushel there would be an equal profit of $47.73.

The estimates were made in the same way for the soy-bean and cowpea acres.

RESULTS OF STEER ACRE WORK 1908-1914

General outline of experiments

It was found that in the experiments published in Bulletin 79 advantage was not taken of the climate of this State, which makes it possible to grow two mature crops on the same piece of land each year. After the removal of the crops in the year 1907, the double-crop system was inaugurated. Barley was sown on the land after the removal of the crops grown during the summer, and was allowed to mature the following spring, and then harvested as grain. The barley grain was fed each year along with the other crop grown on the acre, and thus the total food-nutrient production of the acre was greatly increased, and greater gains per acre were secured. The winter crop of barley was harvested in time to replant this land to soy beans, cowpeas, and corn.

Object of experiments

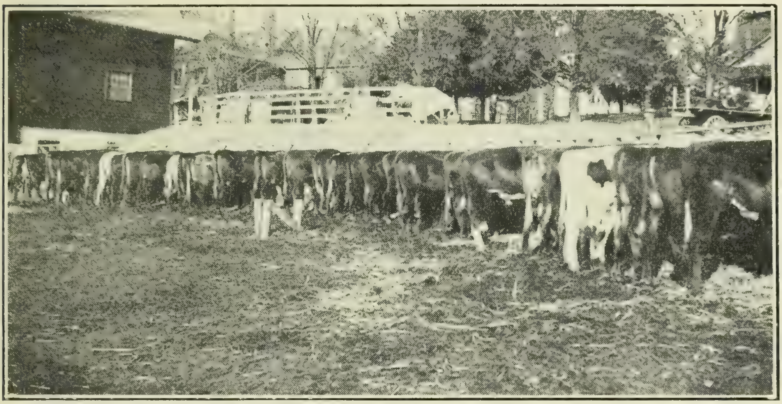
The object of these experiments has been to encourage the feeding of live stock in this State. Naturally, farmers who plan to engage in this type of farming wish to know (1) which kinds of crops will produce the largest yields, (2) which kinds of crops will produce the largest amount of beef when fed to finishing steers, (3) which kinds of rotations are best adapted for the feeding of beef steers, (4) which are the best means of harvesting the various crops when they are intended for cattle-feeding, (5) whether or not the crop should be fed off through heavy feeding in a short time or should be fed in lighter feeds extending over a longer period of time, and (6) which crops will deplete the soil most rapidly.

Crop rotations used In these experiments not all of the crops that may be grown in this State have been experimented with, but only the principal crops. Those that have been tried thus far are soy beans, corn, soy-bean hay, wheat, oats, alfalfa, and barley. These crops were incorporated into rotations, and the experiments have been with those rotations. The rotations were as follows:

Acre I—Barley and soy beans

Acre II—Barley and cowpeas

Acre III—Barley and corn



Steers on Preliminary Feed

Acre IV—Barley and soy beans, with the soy beans harvested as hay

Acre V—Wheat and soy beans

Acre VI—Oats and soy beans, with the soy beans taken off as hay

Acre VII—Alfalfa hay

After the experiments had been conducted for three years, visiting farmers often said they believed that if the soy beans on Acre I were taken off as hay the crop from this acre would produce as good results as if it were taken off as grain and would have the added advantage of being out of the way early in the season so that the barley could be put in earlier. Some suggested that wheat might give better results than winter barley. Still another suggestion was that oats as a winter crop might give better returns. An alfalfa-hay acre was added to the series beginning with the year 1910.

Plan of experiments The plan of the experiments for the first two years was that the crop grown in the summer should be taken off and fed to a group of steers, and that the crop grown in the winter should be turned under in the spring. After the experiments had been conducted according to this plan for two years it was observed that it might be better to harvest the winter-grown crop for grain and then put the acre into a summer crop, to be harvested as grain or hay as seemed best. There appeared to be no reason why the winter crop could not be grown to maturity in this climate and still leave time enough for the growth of the summer crop. The feeding of the winter crop would of course destroy some

STEER ACRES WITH WINTER GRAIN IN SHOCK

of the organic matter, but it was thought that the manure, which was returned to the acre that produced it, would more than supply the organic matter actually needed for the building up of the soil. There would also be the advantage of securing an added return from the winter-grown crop before it should be returned to the acre that produced it. The first two years' work with the single-crop method was published in Bulletin 79. In 1908 it was decided to revise the methods as noted above. The original crops experimented with were soy beans, cowpeas, and corn. In the new outline, barley was to be added to the rotation and to be fed along with the summer-grown crop. Other rotations were added, as follows: In 1909 barley and soy beans, the latter crop to be taken off as hay, were added as Acre IV; in 1911 winter wheat and soy beans were added as Acre V; in 1911 winter oats and soy beans as hay were added as Acre VI; and in 1910 an acre of alfalfa was added.

Basal ration

In all of the experiments a basal ration of 20 pounds of silage per day was added to the ration of each steer. In the calculation of the financial returns for each acre the silage was estimated at $3.00 per ton. Corn and sorghum silage was used in all experiments. At $3.00 per ton each acre of silage used for feeding gave a return of from $33.00 to $48.00 per acre.

Dates of seeding

Up to the year 1911 the barley was sown on the same date on all the acres. Since then the practice has been followed of sowing the barley as soon after the harvesting of the summer's crops as the ground could be got ready. Up to the year 1911 the average date of seeding in the fall was from October 17 to 24. Since the year 1911 the average date of seeding for Acres I, III, and IV has been from October 17 to 29, and for Acres II, IV, and V from September 26 to October 1. The reason for changing the methods of seeding so that the winter crops could be put in as soon as the summer crops were removed was that it seemed unfair not to allow the cowpea acre and the acres in which the soy beans were taken off as hay the natural advantage that they would have in practice of an earlier seeding of the winter crop of barley, which would insure a larger yield of that crop.

Date of harvesting

The average date of harvesting of the barley acre was in the first week of June; of the wheat acre from June 5 to 10; and of the oat acre from June 10 to 15.

Preparation of soil

As soon as the winter-grown crops were harvested, the ground, if hard, was broken up with the subsoil plow, and then fitted for the summer crops as soon as there was sufficient moisture. If the ground was in good condition at the time of harvest, with plenty of moisture, it was plowed and fitted. In the fall, in preparation for the winter crop, the ground was usually broken immediately after the removal of the summer crop, by the running of the subsoil plow every two feet. The subsoil plow, or the turning plow, was always followed immediately with a culto-packer and then a harrow.

Varieties and methods of harvesting

The varieties and rates of seeding of the various crops grown were as follows:

Soy beans (Mammoth Yellow) sown at the rate of 70 to 80 pounds per acre, in rows 24 inches apart, where the crop was to be taken off as grain. Where the soy beans were intended to be taken off as hay they were sown at the rate of 90 to 100 pounds per acre, in rows 24 inches apart.

Cowpeas (Whippoorwill) sown at the rate of 60 to 75 pounds in rows 24 inches apart.

Corn (Hickory King) drilled with the corn planter, in rows 38 inches apart, at the rate of 25 to 30 pounds per acre, and then thinned

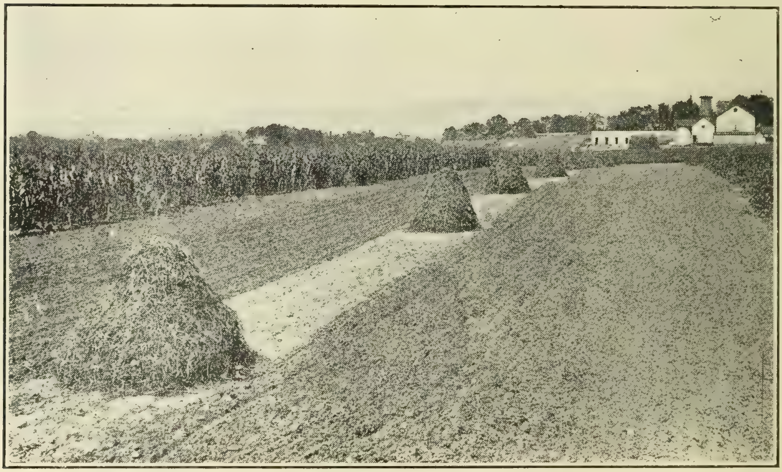
to a stand of 18 to 20 inches in the row. This, perhaps, would not be the best field practice, but for experimental purposes it insured a stand.

Wheat (Poole) sown at the rate of 1½ bushels per acre.

Oats (Culberson) sown at the rate of 2 bushels per acre.

Barley (a mixture of Union and Tennessee) sown at the rate of 75 to 80 pounds per acre.

All the grains were harvested when the grain was ripe. The rule for harvesting the soy beans as hay was to cut them at 15 to 20 days after they were in bloom. At this state the beans are just beginning to form the pod so that they are not noticeable. The hay



Cowpea Acre, Showing Method of Harvesting and Preparing Ground for Succeeding Crop. Hay Cured on Racks

crops were well cured on racks, and then weighed when taken into the barn. The grains were weighed just after they were threshed, as were also the stovers resulting from the threshing. The corn in the fall, when it was desired to begin the feeding, was too wet to grind and feed, and it was therefore measured with the bushel basket, and then an equal measure of old corn was weighed and ground and fed.

Preparation of crops for feeding

The grains were ground before feeding, and the corn was ground with the cob. All stovers were run through the cutting box, as were also the hays. The hays and stovers from each acre were kept separate.

Calculating rations As soon as the amounts of grain, hay and stover were known for each acre, rations for each 30 days were made out for the 90-day periods, or the 60-day periods, according to whether or not it was the intention to run the feeding for 90 or 60 days. Increases in the grain rations were made at the beginning of the second and third 30-day periods when the experiment was to run for 90 days, and at the beginning of the second and third 20-day periods when the experiment was to run for 60 days.

Handling manure The manure produced from each acre was returned to that acre. Manure was left in the stall until mornings when the ground was frozen hard enough to hold up a team and a manure spreader. Thus all the fertility passing through the steers, that was produced from a particular acre, was returned to that acre. Thus far there seems to be no diminution in the fertility of those acres where a leguminous crop is grown at some time during the year. From the appearance of the corn grown on Acre III, there seems to be a diminution in the fertility of that acre. The other acres are gathering nitrogen from the air, which appears to keep up that element in those acres sufficiently to insure good crops.

Method of selecting steers, and preliminary feeding The steers selected each year would grade as medium-to-good feeders on the Chicago market, and were from cattle produced in Tennessee. They were mostly of Shorthorn breeding; some of them, however, were of Angus breeding, and a few were Hereford grades. The steers were usually selected in August or the fore part of September, and were got into the feed-lot about the latter part of October. For a period of three weeks the steers were put on a preliminary feed of corn stover, green corn, and green sorghum, and some hay. From 50- to 100-pounds fill was secured in this manner during the three weeks. The steers were then numbered with wooden blocks suspended from the neck, and were weighed individually for three days, the average weight being taken. They were then divided into groups of four, according to weight, and quality, and the experiment proper was begun.

Weighing of steers The steers were weighed individually for two days at the end of every 10 days, and for three days at the end of every 30- or 20-day period, according to whether the experiment was to run 90 or 60 days.

Feeding and care During the actual time that the steers were on experiment they were fed twice daily, the day's ration being divided equally between the two feeds. They were fed between five and six o'clock in the morning and between five and six o'clock in the afternoon. In the afternoon, when the weather was favorable, they were turned into one common lot,

where they had access to water. The stalls were then bedded with straw produced from the acres. Each ration was carefully weighed and the roughage and the concentrates were thoroughly mixed.

Numbering of steers At the beginning of the experiment numbers were cut in the hair on the hips by means of curved shears, which were better than the blocks because the steers were more easily distinguishable and the numbers could not be lost.

TABLE XII—*Crop yields of acre experiments*

No. of acre	Crops grown	1908	1909	1910	1911	1912	1913	1914	Average	
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bu.
I	Soy-bean grain	984	1020	1560	1174	1300	667	1616	1189	19.8
	Soy-bean stover	2800	3190	3570	2740	2270	2235	3335	2877	
	Barley grain	1920	1104	1412	1276	1440	1512	1211	1411	29.4
II	Cowpea grain	690	360	510	684	755	315	543	550	9.2
	Cowpea stover	2180	2110	2070	2280	1800	1615	2675	2104	
	Barley grain	1920	1512	1515	1307	1390	2106	1837	1656	34.5
III	Corn grain	1572	1680	2835	2450	1260	1395	1680	1839	26.3
	Corn stover	3583	2560	3524	3855	2645	2150	3000	3045	
	Barley grain	1920	1240	1486	1226	1240	1030	1181	1332	27.8
IV	Soy-bean hay		4000	3865	3555	3370	3455	4120	3727	
	Barley grain		1104	1472	1418	1350	1716	1598	1443	30.0
V	Soy-bean grain				1067	1166	746	1828	1202	20.0
	Soy-bean stover				2595	2540	2040	3035	2552	
	Wheat grain				1200	1200	1390	1072	1216	20.3
VI	Soy-bean grain				1067	1324				
	Soy-bean hay						2165	3615	3376	
	Soy-bean stover				2595	2745				
	Oat grain				2080	1472	1998	892	1610	50.3
VII	Alfalfa hay			9860	7000	8205	7500	8577	8228	

Crop yields

In the original outline of these experiments provision was made that they should cover for each acre a period of ten years in order that the agencies affecting yields, such as weather conditions, and individual variations of steers, would be distributed over a long enough period of time so that the error from those sources would be reduced to the minimum. This bulletin is, then, only preliminary to the final report that will be published when all the data are complete. Results from the acres that have been on experiment for seven years may be considered conclusive, but those from the acres that have been on ex-

SOY-BEAN ACRE ON RIGHT; COWPEA ACRE ON LEFT

periment for less time than that should not be taken as conclusive. It was also desired to carry on the experiment for a period of ten years so that any increase or decrease in yield per acre could be observed.

Table XII shows the yields for each year, and the average yields per acre for each acre.

Crop yield per acre

Acre I produced an average of 2,600 pounds of grain; Acre II, 2,206 pounds; Acre III, 3,171 pounds; and Acre V, 2,418 pounds. The yield for the corn acre is given as the weight of corn and cob, and therefore does not quite compare with the other acres. Acre I ranks ahead of all other acres in the amount of food material produced. Soy beans rank ahead of cowpeas in the production of grain each year. Cowpeas were ready for harvest earlier in the season each year, and therefore allowed for the collection of more moisture in the ground

previous to the barley seeding, or made it possible to sow the barley earlier in the season, as has been done since 1911, and thus insured a better crop of barley than was produced on the other acres. The increase in barley, however, did not compensate for the decrease in summer grain produced. Where soy beans are taken off as hay, thus permitting the winter grain crop of barley to be sown at an earlier time, the barley will yield practically as well as when sown after cowpeas. This fact is shown by the yields on Acre IV as compared with Acre II, since the year 1911, when the practice was adopted of sowing the winter crop on each acre as soon as the summer crop was removed. Cowpeas do not remove as much moisture from the ground upon which they are growing as do soy beans, owing to the fact that they do not produce as large a crop of grain and stover.

Effect of leguminous crops in the rotations

In every one of the rotations planned for the experiment, with the exception of Acre III, there is included in the rotation a leguminous crop, and a careful study of the table will show that in every one of the acres there seems to be a tendency for the crop yields to remain on a par with those of the first two or three years of the experiment, with the exception of Acre III, where the crops grown are barley and corn. The barley yields on that acre have been constantly on the decrease, and there seems to be a tendency for the corn yields to decrease. There is no nitrogen-gathering crop in the form of a legume, and manifestly the nitrogen content is on the decrease, and thus the yields are on the decrease.

Beef yields per acre

The primary object of these experiments was to determine the amounts of beef that an acre of land would produce if the crops grown upon it were fed to live stock. Table XIII shows the amounts that have been

TABLE XIII—*Gains produced per acre*

No. of acre	Crops grown	1908	1909	1910	1911	1912	1913	1914	Average gain per acre
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
I	Soy beans and barley	673	632	609	420	364	367	494	508
II	Cowpeas and barley	529	561	441	305	366	528	370	451
III	Corn and barley	602	476	708	350	169	355	378	434
IV	Soy-bean hay and barley		617	461	393	241	518	372	435
V	Soy beans and wheat				354	347	493	412	402
VI	Soy-bean hay and oats				570	400	485	367	456
VII	Alfalfa			758	302	431	581	502	515

produced up to the present time with the various rotations of crops grown.

These experiments show that better results in beef production can be secured from a rotation of soy beans and barley than from any other combination of crops used in these experiments. The rotation

TABLE XIV—*Ranking of acres according to beef yield*

No. of acre	Crops grown	No. of years on experiment	No. of times that acre ranked							Average rank
			1st	2nd	3rd	4th	5th	6th	7th	
I	Barley and soy beans	7	2	2	1	1	---	1	---	2
II	Barley and cowpeas	7	---	1	3	2	---	1	---	4
III	Barley and corn	7	1	1	---	2	---	1	2	6
IV	Barley and soy-bean hay	6	---	1	3	---	1	1	---	5
V	Wheat and soy beans	4	---	---	1	1	2	---	---	7
VI	Oats and soy-bean hay	4	1	1	---	---	1	---	1	3
VII	Alfalfa	5	3	---	1	---	---	---	1	1

in which soy beans were used produced an average of 57 pounds more beef than that in which cowpeas were used, and 74 pounds more than that in which corn was used. Larger gains were obtained when the crop was harvested at maturity than when it was made into hay. This is clearly brought out by a comparison of Acres I and IV. On the latter acre the soy beans were harvested as hay and on the former acre they were harvested as grain. Acre I produced an average of 70 pounds more than Acre IV. While this amount for one acre may not seem large, for ten acres there would be produced 700 pounds more beef when the crop was taken off as grain than when it was taken off as hay. This means that, with beef selling at 6 cents per pound, the method used on Acre I would return $42.50 more per ten acres than the method used on Acre IV.

It is especially worthy of note that corn and barley, the rotation used on Acre III, gave the lowest average returns in beef yield of all the rotations on experiment, with the exception of Acre V, soy beans and wheat. Acre V, however, has been on experiment for only four years, and shows a tendency to produce larger yields than the corn and barley rotation for the last three years. The corn and barley rotation is not to be recommended on account of its low beef yield, the difficulty of operation, and the constantly decreasing crop and beef yields, due to the constantly decreasing nitrogen content of the soil. Table XIV shows the number of years that each of the acres ranked first.

It is evident that no conclusions can be drawn from the results of any single year. To determine the yield of beef that may be made per acre, the average results of several years must be taken.

Ranking of acres

The alfalfa acre has ranked first in yield of beef for three years and last for one year. In beef yield this is the ranking acre. It has not, however, been on experiment so long as some of the other acres. The soy-bean and barley acre ranked ahead of it in gross returns per acre.

Corn Acre on Right; Cowpea Acre on Left

The soy-bean and barley acre has ranked first for two years and second for two years. It has never ranked lowest. Five of the seven years it has ranked among the upper half of the acres in beef production.

Oats and soy-bean hay have been on experiment for only four years. They have made a good showing for that time, but not enough results have been obtained from them to warrant the drawing of conclusions.

The cowpea and barley acre has not averaged so well as the soy-bean and barly acre. It has never ranked first in production. It has, however, for three years produced more than 500 pounds of beef per acre.

The corn and barley acre thus far has proved to be nearly the poorest of the acres for the production of beef. This acre has ranked, five years out of the seven, in the lower division. The use of corn

and barley as a rotation for the growing and finishing of beef cattle is not to be recommended as compared with soy beans and barley.

Gross returns per acre

In order to determine the gross returns per acre, the following method of calculation was employed: The beef produced was valued at 6 cents per pound, the silage fed at $3.00 per ton, and it was assumed that there would be a margin of $1.00 on 1,000-pound steers for the feeding period. Table XV is calculated on this basis, and shows under these conditions the returns per acre when the crops were fed to finishing steers.

TABLE XV—*Gross returns per acre with beef produced at 6 cents per pound, silage fed at $3.00 per ton and $1.00 margin on 1000-pound steers for 60 to 90 days*

No of acre	Crops grown	1908	1909	1910	1911	1912	1913	1914	Av.
I	Soy beans and barley	$69.58	$67.12	$65.74	$54.40	$54.64	$54.82	$62.32	$61.23
II	Cowpeas and barley	61.54	66.46	59.26	51.10	54.76	64.48	55.00	58.94
III	Corn and barley	65.32	57.76	71.68	51.20	42.94	54.10	55.48	56.92
IV	Soy-bean hay and barley		66.22	56.86	53.08	47.26	63.88	55.12	57.07
V	Soy beans and wheat				50.44	53.62	62.38	57.52	55.99
VI	Soy-bean hay and oats				63.40	56.80	61.90	54.82	59.23
VII	Alfalfa hay			71.08	47.32	53.74	64.06	58.36	58.91
	General average								$58.34

Comparison of gross returns per acre

The soy-bean and barley acre ranked first in the gross returns per acre, with the alfalfa acre a close second. The alfalfa acre, however, has been on experiment for a shorter period of time, and therefore the data cannot be so nearly conclusive. The striking thing to be noted is that the returns for each of the acres are good even though the margin between the purchase price and the selling price of the cattle be but $1.00. If the margin between the purchase price and the selling price were $1.50 then the returns per acre would be from $5.00 to $6.00 greater than those given in the table.

While these results seem high, it must be observed that they are gross returns per acre, and no account has been taken of the cost of production. On the other hand, the labor has been evenly distributed throughout the year by the utilization of the crops for the feeding of steers during slack seasons. After all, the farmer is most interested in the gross returns per acre if the work can be done with the labor which he has already at hand.

The average gross returns are as follows:

Acre	Years	Average gross returns
Soy beans and barley	7	$61.23
Cowpeas and barley	7	$58.94
Corn and barley	7	$56.92
Soy-bean hay and barley	6	$57.07
Soy beans and wheat	4	$55.99
Soy-bean hay and oats	4	$59.23
Alfalfa hay	5	$58.91

These returns would indicate that the finishing of beef steers could be profitably practiced on $100-$150 acre land, where the land was fertile and the cultivation intensive. The returns from these acres will illustrate the possibilities of the South for beef production in a system by which more than a single crop is grown each year.

Time in which crop should be fed off

A question that is often asked is, whether or not it is better to finish steers with a heavy or with a medium ration of grain. It is of course well known that heavy grain rations will make the larger gain for the same length of time, but the gains thus far have not been related to the acre basis. The farmer feeds crops to beef cattle in order to utilize the roughage grown on the farm, to secure a larger price for his products than he would on the market, and to conserve his soil fertility. These experiments have been conducted so as to determine whether it would be better to feed up the crops grown in a short feeding period with a heavy ration, or to feed a lighter grain ration and thus extend the time for finishing. During the last three years of the experiments the crops grown have been

TABLE XVI—*Comparison of lengths of time of feeding the crops produced*

No. of acre	Crops grown	When fed in 90 days			When fed in 60 days		
		No. of years	Average gain	Average gross returns	No. of years	Average gain	Average gross returns
I	Soy beans and barley	4	584	$64.21	3	375	$57.26
II	Cowpeas and barley	2	447	56.32	5	453	59.99
III	Corn and barley	4	527	61.49	3	301	50.84
IV	Soy-bean hay and barley	3	492	58.38	3	277	55.42
V	Soy beans and wheat	1	354	50.44	3	417	57.84
VI	Soy-bean hay and oats	1	570	63.40	3	417	57.84
VII	Alfalfa hay	5	515	58.91	---	-----	-----
	Averages*		496	$59.04		373	$56.53

*Not including alfalfa acre.

fed up in a feeding period covering 60 days. In Table XVI the experiments have been grouped according to the length of time in which the crops grown have been fed.

Results from 60- and 90-day feeding periods

The averages of the results given in Table XVI do not include the data for the alfalfa acre, since it appears on but one side of the table. The average beef yield for all the acres on experiment, excepting the alfalfa acre, when they have been fed off in 90 days, was 496 pounds, while the average for the same acres when they were fed off in 60 days was 373 pounds. The returns in beef yield per acre were 33 per cent larger when the crops grown were fed off in 90 days than when fed off in 60 days. The average gross returns for the 90-day feeding period were $59.04, and for the 60-day feeding period $56.53. The increased finish which the steers on 90-days feed put on would likely make them bring from one-fourth to one-half cent more per pound than the steers on 60-days feed. The steers on the 90-days feed made more gains than the steers on the 60-days feed, owing to a greater utilization of the roughages grown on each acre.

Farm values of feed fed

In the following discussion we have tried to determine the gross returns for each pound of hay or grain when sold through the steers. The data have been derived from Tables XII and XV. In the calculation, on the weight basis, the grains have been considered of equal value for feeding purposes. The hays were calculated at two-thirds the value of the grain. Table XVII gives the prices obtained for grains and hays grown on the acres on experiment when sold through the steers fed from those acres. The table also gives the price that each bushel of grain would have to bring when sold off the farm to equal the price obtained when sold through steers and in addition pay for the fertilizer that would have to be purchased in order to equal the fertility returned by the steers. The fertilizer content of the feeds was calculated from Henry and Morrison's "Feeds and Feeding," Appendix, Table III, and it was assumed that 80 per cent of the fertilizing elements was returned through the manure.

Prices received for crops fed

From Table XVII it will be seen that the average prices received for the crops fed the steers were as follows: Soy beans, $1.40 per bushel; cowpeas, $1.60; wheat, $1.39; oats, $.57; barley, $1.02; corn, $1.00; soy-bean hay, $17.50 per ton; alfalfa hay, $14.20 per ton. These prices were obtained for the feeds fed from the acre, and it is estimated that 80 per cent of the fertilizing elements contained in the feeds was returned to the acre that grew the crop. If the crops had been sold on the market as grain and hay these elements would have been lost to the acre that produced the crop unless replaced through commercial fertilizer. In the righthand column is shown the price that each would have to sell at in order to equal the price received for each when sold through the steers, and also to pay for 80

TABLE XVII—*Prices obtained for grains and hay by marketing through steers. Also prices they must sell at when not fed to make up for fertility returned by steers when fed*

No. of acre	Feed grown	Average No. pounds grown	Gross returns obtained when sold through steers: Per pound	Gross returns obtained when sold through steers: Per bu. or ton	Price each must sell at when not fed to make up for fertility* returned by steers
			Cents		
I	Soy beans	1189	2.35	$ 1.41 per bu.	$ 2.06 per bu.
	Barley	1411	2.35	1.13 per bu.	1.31 per bu.
II	Cowpeas	550	2.67	1.60 per bu.	2.03 per bu.
	Barley	1656	2.67	1.28 per bu.	1.45 per bu.
III	Corn	1839	1.80	1.00 per bu.	1.17 per bu.
	Barley	1322	1.80	.86 per bu.	1.04 per bu.
IV	Soy-bean hay	3727	.86	17.20 per ton	27.59 per ton
	Barley	1443	1.72	.83 per bu.	1.06 per bu.
V	Soy beans	1202	2.32	1.39 per bu.	2.04 per bu.
	Wheat	1216	2.32	1.39 per bu.	1.60 per bu.
VI	Soy-bean hay	3376	.89	17.80 per ton	28.39 per ton
	Oats	1610	1.79	.57 per bu.	.69 per bu.
VII	Alfalfa hay	8228	.71	14.20 per ton	24.03 per ton

*Fertilizing elements were valued at 20 cents for nitrogen and 5 cents each for phosphoric acid and potash, and it was assumed that 80 per cent of the fertilizing elements of feeds fed to steers was returned to the acre that produced the crop.

per cent of the fertilizing elements contained in each feed produced on the acre; for that amount of fertilizing elements must necessarily be returned in order to equal the gross returns when the crops are fed to steers. If sold as grain or hay and the fertilizing elements reckoned as a factor, then in order to equal the returns when sold through feeding to steers the crops would have to sell at the following prices: Soy beans, $2.05 per bushel; cowpeas, $2.03; wheat, $1.60; oats, $.69; barley, $1.21; corn, $1.17; soy-bean hay, $27.99 per ton; alfalfa hay, $24.03 per ton. The question of the fertilizing elements contained in a bushel of grain or a ton of hay is too large a factor to be ignored in considering the profits of any crop produced on the farm today. If the fertilizing elements are sold from the farm in this generation they must be replaced in the succeeding generation. The farmer cannot eat his cake and have it too. He cannot sell his farm fertiltiy and have it too. Fertility is an asset, and if sold from the farm it must be replaced at some future date just as destroyed buildings or fences must be replaced.

Agricultural Experiment Station

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FACTORS INFLUENCING THE LIME AND MAGNESIA REQUIREMENTS OF SOILS

A METHOD FOR THE DETERMINATION OF THE IMMEDIATE LIME REQUIREMENTS

BY

W. H. MACINTIRE

KNOXVILLE, TENNESSEE

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LETTER OF TRANSMITTAL

Department of Chemistry and Agronomy
Agricultural Experiment Station
University of Tennessee
Knoxville

August 2, 1915.

Prof. H. A. Morgan, Director.

DEAR SIR:

A considerable part of the data and many of the statements and conclusions given in this manuscript have been published in Bulletin 107 of this Station. However, in order to present the subject of the factors influencing the lime and magnesia requirements of soils as clearly and in as nearly complete a form as possible, from the point of view entertained, such a restatement appears to me to be necessary and to add materially to the value of the additional data obtained. I therefore recommend that this manuscript be published by the Station as a research bulletin.

Very respectfully,

C. A. MOOERS,

Chemist and Agronomist.

FACTORS INFLUENCING THE LIME AND MAGNESIA REQUIREMENTS OF SOILS

A METHOD FOR THE DETERMINATION OF THE IMMEDIATE LIME REQUIREMENTS

By

W. H. MacIntire

The work reported in this bulletin was begun in the spring of 1912, and was undertaken as an "Adams Fund" project. The investigation was based upon a study of the factors influencing the decomposition of $CaCO_3$ in the determination of the lime requirement of soils. The Veitch method[1] was taken as the original basis of the study. Some results bearing upon certain phases of the work have been reported elsewhere by the writer and his associates.[2] When the present work was undertaken there had been proposed only two quantitative methods, other than the method of Veitch, in which lime requirements were determined by the direct application of lime to soils. Tacke[3] agitated a mixture of soil and $CaCO_3$, and from the estimation of liberated CO_2 calculated the amount of $CaCO_3$ decomposed. Süchting[4] concluded that the continued evolution of CO_2 during the long period of contact of the Tacke method results in part from the action of carbonate of lime upon neutral organic matter. Süchting modified Tacke's method by agitating the soil and an excess of $CaCO_3$ for two hours, drawing off and discarding the liberated CO_2. The residual $CaCO_3$ is then determined by treatment with 20 per cent HCl and aspiration with agitation for 1 hour. Hydrogen is used as a current of gas to remove the CO_2. Süchting thus contends that the action of the sparingly soluble $CaCO_3$ upon organic matter is greater than that exerted by strong acid during extended periods of contact at normal temperatures. This is not at all in accord with the experience of the writer, who believes that the fallacy of the contention is at once apparent. It will be shown that the continued evolution of CO_2, which results from an extension of the period of contact of soil and carbonate, is the result of a continued reaction be-

1. Jour. Am. Chem. Soc., 1902, Vol. 24, p. 1120.
2. Tenn. Station Bul. 107.
3. Chem. Ztg., 1897, Vol. 21, p. 174.
4. Zts. Agnew Chem., 21, (1908), No. 4. p. 151.

tween $CaCO_3$ and acid silicates, as well as a possible result of action of $CaCO_3$ upon soil organic matter. As will be shown later, neither of these last two named procedures effects maximum decomposition of a carbonate in the case of an acid-clay subsoil, in which instance consideration of the question of organic matter is eliminated.

Of the three methods, that of Veitch has been most generally accepted in this country. It was thought possible that an investigation of the principles involved in the Veitch method might lead to a modification which would expedite the manipulation of the determination, while retaining its salient features and accuracy. It was also intended to conduct supplementary basket experiments in order to determine any correlation between laboratory results and plant response. Since the completion of much of the work herein reported, a method has been described by Hutchinson and MacLennan[1]. This method consists of the agitation of the soil for 3 hours with $CaCO_3$ in solution of carbonated water and then filtering. The difference in the alkalinity of the original solution and that of the filtrate is taken as a measure of soil acidity. Without wishing in any way to detract from the priority of claim to publication of the innovation of using a solution of $CaCO_3$, which priority rightfully belongs to Hutchinson and MacLennan, the writer would state that the method given at the end of this article had been perfected prior to his knowledge of the work of Hutchinson and MacLennan, whose method appeared a few weeks in advance of the November (1914) meeting of the Association of Official Agricultural Chemists, to which body the Tennessee Station method was proposed. The paper giving the essentials of the latter method was published in the abstracts of the proceedings of the Association[2]. The Association's Referee for soils is now studying these two methods, which direct that $CaCO_3$ be used in solution. The work of Hutchinson and MacLennan was brought to the attention of the writer at the meeting above mentioned. A copy of the article was then secured and the method tested and compared with the one proposed by the writer. The results of the comparison are given later in this report.

The various procedures suggesting the use of different soluble salts of the several alkalis were not included in the study. Several of these proposed absorption methods have embodied very neat manipulation and rapid handling under laboratory conditions—features which appeal to the laboratory worker. Extensive bibliographies of these various quantitative and qualitative procedures have been presented in several recent publications,[3] and will not therefore be included in this bulletin. Such methods are predicated upon the assumption of chemical equivalence between the amounts of bases extracted by soil from readily soluble neutral salts and the amount fixed by the soil from the relatively insoluble carbonate. The methods have no basis upon which they may be legitimately compared to actual

1. Chem. News, England, 110 (1914), No. 2854.

2. American Fertilizer, Nov. 28, 1914.

3. Frear, Wm., Dept. of Agr. Com. of Pa., Harrisburg, Bul. 261, pp. 103-106. See also, Conner, S. D., Jour. Ind. and Eng. Chem., vol. 8, No. 1, p. 35.

conditions existing in field soils. The results of such methods must, however, be interpreted from terms of the salt used into terms of burnt or carbonated lime, in order to be in harmony with practice. Sodium and potassium nitrate tend to produce alkalinity when applied to field soils, but any liberated acid does not leach away uncombined, as in the laboratory procedure; yet the liberation of the acid radical under laboratory conditions has been used as a measure of acidity, or lime requirement.

Previously published work of the writer and his associates has shown that there was a constant and vast difference between the reaction of the closely allied carbonates of calcium and magnesium upon three distinct types of soil, which were studied in pot and cylinder experiments under normal conditions. Now, if there exist this vast difference between the reaction of acid-reacting soil constituents upon $CaCO_3$ and that upon $MgCO_3$, it would seem to indicate as fallacious the assumption of equal or proportional activities between the carbonate of calcium and the other neutral salts of the same element. The same would apply in the case of the various suggested salts of the other bases. We know that we cannot assume that there would be an equivalent dissociation of the salts of corbonic, oxalic, acetic, nitric, sulphuric and other acids, nor that the bases of these several salts would be absorbed in equal or equivalent amounts by the same acid salts[1].

The writer was of the opinion, when beginning these studies, that the correct procedure to be followed in the determination of the lime requirement of a soil involved contact between the soil and calcium carbonate, the material generally used in practice. He continues in this belief and is entirely in accord with Harris[2], who states, "The only sure way to determine the lime requirement of an acid soil is to use the same material in the test as is used in the field, for correcting the acidity."

The different treatments given in this bulletin were therefore based upon the reactions effected by bringing both the "C. P." and the natural carbonates of calcium and magnesium into contact with soils and soil constituents, under various conditions, normal and forced. By so doing it was hoped to determine definitely some facts concerning the results of the treatment of soils with calcium and magnesium carbonates, the forms more generally used in practice.

MEASURE OF TREATMENTS

In laboratory work upon the Veitch method, supplemented by extensive pot work, Gardner and Brown[3] studied the soils of the 36 treatments and checks of the General Fertilizer Experiment plots at the Pennsylvania Station. Burnt lime and ground limestone were applied in amounts indicated by the Veitch method. Clover was sown and twice

1. See Parker, E. G., Jour. Agr. Research, 1913, vol. 1, No. 3; Harris, J. E., Mich. Agr. Exp. Sta., Bul. 19; Conner, S. D., Jour. Ind. and Eng. Chem,, vol 8, No. 1, p. 35.
2. Science, Oct. 2, 1914, p. 493.
3. Pa. Station, Report, 1910-11, pp. 25-76.

TABLE I—*Reactions of soils to litmus and Veitch tests after treatments of $CaCO_3$ and $MgCO_3$, based upon the Veitch-method indications*

	Sandy loam								Silty loam								Loam							
Treatment	$CaCO_3$				$MgCO_3$				$CaCO_3$				$MgCO_3$				$CaCO_3$				$MgCO_3$			
Amount*	V.†	V.+	V.+	V.+	V	V.+	V.+	V +	V.	V.+	V.+	V.+	V.	V.+	V.+	V.+	V.	V.+	V.+	V.+	V.	V.+	V +	V.+
		⅓	1785	16070		⅓	1785	16070		⅓	1785	16070		⅓	1785	16070		⅓	1785	16070		⅓	1785	16070
Reaction to litmus	Acid	Acid	Neut	Alk.	Acid	Acid	Neut.	Alk.	Acid	Acid	Acid	Alk.	Acid	Acid	Acid	Alk.	Acid	Neut.	Neut	Alk.	Acid	Neut.	Neut.	Alk.
Reaction to Veitch method	Acid	Acid	Acid	Alk.	Acid	Acid	Acid	Alk.	Acid	Acid	Acid	Alk.	Acid	Acid	Acid	Alk.	Acid	Acid	Alk.	Alk.	Acid	Acid	Alk.	Alk.

*Pounds per acre 3,500,000 pounds of soil.

† "V." signifies indication by the Veitch method.

harvested. Eight months after treatment a second series of analyses were made by the Veitch method. An average of these last analyses gave 29 per cent and 28 per cent of the original lime requirements for treatments of burnt lime and limestone, respectively. Accordingly, in making applications of $CaCO_3$ in pot work upon soil of three distinct types, with the intention of learning the relation of the Veitch-method results to the absolute, the writer planned to apply the amount of the Veitch indication and also the Veitch requirement plus one-third. Applications of both 1785 pounds and 16070 pounds of $CaCO_3$ per acre 3,500,000 pounds of soil in excess of the Veitch method were also made. These amounts represent 1000 pounds and 9000 pounds, respectively, of CaO in excess of the Veitch-method indications. Kalbaum's "C. P." precipitated carbonate was used and the treatments were thoroughly mixed throughout the soil. In order to eliminate consideration of root growth and utilization of lime as plant food, portions of the soil were kept fallow for the subsequent analytical work. Other portions were sown to wheat. The heavy amount was included, both to determine the effect of the excess upon plant growth and to insure an appreciable amount of residual carbonates, the determinations of which would afford a means of establishing, quantitatively, the amount of $CaCO_3$ decomposed above that indicated by the Veitch method. As a parallel study, the various treatments based upon the Veitch-method indications were checked by applications of chemically equivalent amounts of Kahlbaum's "C. P." $MgCO_3$. Three soils, a loam, a sandy loam, and a silty loam, were selected for study. The Veitch-method requirements of these three soils per 3,500,000 pounds of soil were 6807 pounds, 2350 pounds, and 1894 pounds of $CaCO_3$ for the loam, the sandy loam, and the silty loam, respectively, on moisture-free basis. Whenever used in terms of pounds per acre, and when making comparisons between residual carbonates, as well as when stating extent of the dissipation of CO_2, the magnesium carbonate amounts stated are in terms of $CaCO_3$ equivalence. Three paraffined wire baskets of approximately 25-pounds capacity each were used for each treatment of each soil. The soils in the baskets were sown to wheat October, 1912, and the wheat was harvested in February, 1913. The yields resulting from the various treatments have been reported elsewhere.[1] After cropping, the roots were removed and the soils of the check pots, and the pots containing the Veitch plus one-third, and the Veitch plus 1785-pound treatment, were bottled. Each soil was then carefully tested as to its reaction by both Veitch and litmus-paper tests. The results are given in Table I.

The results of Table I confirm those of Gardner and Brown[2]. It is plainly evident from the Veitch tests made over a year after treatment that there is a *continued decomposition* of calcium and magnesium carbonates in the unleached fallow soils. As will be shown later, the soils receiving the heavy $MgCO_3$ treatments were devoid of residual carbonates at the end of the one-year period, but the excess of silicates afforded alka-

1. Tenn. Station Bul. 107.
2. Pa. Station, Report, 1910-11, pp. 25-76.

TABLE II—*Decomposition of $CaCO_3$ and $MgCO_3$ in excess of Veitch-method indications—determined by difference between original and residual carbonates*

Soil type	Treatment	Veitch indication of $CaCO_3$ per acre 3,500,000 lbs. of soil	$CaCO_3$ equivalent added per acre 3,500,000 lbs. of soil	Increase of $CaCO_3$ equivalent, per acre 3,500,000 lbs. found 1 year afterward	$CaCO_3$ decomposed in excess of Veitch indication	
					Per 3,500,000 lbs. of soil	Per cent of original Veitch indication
		Lbs.	Lbs.	Lbs.	Lbs.	
Loam	$CaCO_3$	6807	22877	11288	4782	70.25
Silty loam	$CaCO_3$	2350	18420	6143	9927	422.42
Sandy loam	$CaCO_3$	1894	17964	9961	6109	322.54
Loam	$MgCO_3$	6807	22877	*0	16070	236.06
Silty loam	$MgCO_3$	2350	18420	*0	16070	683.82
Sandy loam	$MgCO_3$	1894	17964	*0	16070	949.52

* Plus or minus error of .008 per cent allowed between original and residual $CaCO_3$ determinations.

linity reactions in both Veitch and litmus-paper tests. The amounts of carbonate decomposed by the continued contact of fallow soil and excess of $CaCO_3$ and $MgCO_3$ are considerably above the original Veitch indications. In the heavy $CaCO_3$ treatments of 16070 pounds in excess of the Veitch requirements, it was anticipated that the residual carbonate would afford a means of measuring the relation between the Veitch requirements and the amounts actually decomposed by the different types of soil. Accordingly, the heavy treatments of $CaCO_3$ and $MgCO_3$ were analyzed for CO_2, by the Tennessee Station method[1], exactly one year after treatment. The results are given, on the moisture-free basis, in Table II.

It will be noted that a considerable portion of the excess of $CaCO_3$ above the Veitch indication and treatment was decomposed. The CO_2 of $MgCO_3$, however, was completely dissipated. This decomposition of $MgCO_3$ was substantiated by analyses of the air-dried composites of fallow soils from eight field cylinders which had received treatments of $MgCO_3$ equivalent to 28,180 pounds $CaCO_3$ per acre 2,000,000 pounds of soil. The loam soil of the baskets was used in this case, and two treatments of $CaCO_3$ in chemical equivalence were analyzed as checks. The cylinder treatments had been made only eight weeks prior to analysis, and no leaching had taken place during the period of exposure. Determinations made by boiling the original soil showed a CO_2 occurrence of .0740 per cent, while .0666 per cent was found as an average of four determinations made by boiling the soils which had received the heavy $MgCO_3$ treatments. The $CaCO_3$ treatments resulted in a gain over the original of 19170 pounds of $CaCO_3$ per acre 2,000,000 pounds of soil.

From these data and succeeding results, it is readily seen that the excessive $MgCO_3$ decomposition noted in Table II was not the limit of the immediate ability of the loam soil to decompose precipitated $MgCO_3$.

Had the different treatments been subjected to leaching, the disappearance of carbonates subsequent to $MgCO_3$ treatments might have been explained by the assumption of a replacement of magnesium for readily leached sodium and potassium. As stated, however, the original soils were in baskets, and were not subjected to leaching during the one-year period of contact, nor did leaching take place during the eight weeks' exposure of the cylinder soils.

The results secured upon determination of residual carbonates demonstrate the existence of a long continued reaction between soils and carbonates. Furthermore, they emphasize the necessity of defining more specifically the term "lime requirement." To the writer, the data seem to necessitate differentiation between temporary, or immediate, lime requirement and the continued propensity of a soil to decompose $CaCO_3$, when soil continues in contact with excess of carbonates. This question also arises. Should the lime requirement of a soil be considered as its maximum coefficient of $CaCO_3$ decomposition, under laboratory conditions in given time, or should it be considered as the amount of lime essential to maxi-

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1. Tenn. Station, Bul. 100; Jour. Ind. and Eng. Chem., March, 1915.

mum crop response for a definite period after treatment, according to relationship to some definite laboratory results obtained under controlled conditions? The feasible procedure would be to determine a method which would effect the maximum decomposition of $CaCO_3$ by its contact with the acid-reacting soil constituents under well controlled laboratory conditions, and then, if possible, to establish a relationship between this maximum decomposition and practice.

The disappearance of $MgCO_3$ presented an additional unanticipated problem, that of determining the reason for this previously unreported tendency. Accordingly, the studies were continued with a view to acquiring data upon both lime and magnesia requirements and the existence of any definite relationship between the activities of the two carbonates which might be attributed to solubility, molecular equivalence, or other factors.

LABORATORY STUDIES

Two of the three soils studied in the pot work were exceedingly low in organic matter, and it was therefore difficult to account for the loss of carbonates by assuming reactions to have taken place between the bases and organic constituents. Consequently a laboratory study was begun to determine the activities of the three soils of Table I and various mineral soil constituents upon the two earthy carbonates. The scheme followed was to bring the soils and carbonates into contact under different moisture conditions, with means of determining accurately the CO_2 evolved from the treated soils. The moisture conditions maintained were air-dry, estimated optimum, and a large excess of water. This, of course, necessitated the elimination of any biological influences. In order to avoid the use of heat for purposes of sterilization, one of the alkaline soils was impregnated with .5 gram benzoic acid, as neutral sodium benzoate, treated with 2 grams of $MgCO_3$ and placed in Erlenmeyer flasks. These preliminary tests as to the influence of different moisture conditions showed that the estimated optimum condition gave the greatest activities, as measured by CO_2 evolutions; but it appeared that there was an interference from the organic salt used to produce sterility.

In order to test this point, the untreated loam soil and some of that which had decomposed the excessive $MgCO_3$ treatment, both being carbonate-free, and the same soil with an accumulation of $CaCO_3$ from its previous heavy treatment, were used to determine the influence of the three conditions of the same soil upon sodium benzoate. The amounts of CO_2 evolved are shown in Table III.

The sterility of the soils treated with the preservative seemed to be beyond question.

It therefore appeared that the catalytic oxidative power of the soil effected oxidation of the sodium benzoate. Hence, its use was discontinued and sterilization was accomplished by steam and maintained through the use of cotton filters and washing solutions.

TABLE III—*Evolution of CO_2 from acid and alkaline soils when in contact with sodium benzoate*

Type	Soil used		Treatment		CO_2 evolved during 147 days' contact
	Amount	Reaction	Previously given	This experiment	
	Gms.				Gms.
Loam	200	Acid	None	Sodium benzoate	.5001
Loam	200	Alkaline	$CaCO_3$—22877 lbs. per acre	Sodium benzoate	.3407
Loam	200	Alkaline	$MgCO_3$—22877 lbs. per acre	Sodium benzoate	.5014

DECOMPOSITION OF EARTH CARBONATES BY STERILE ALKALINE SOILS

Two hundred grams of each of the air-dried soils of Table I were next used for contact carbonate treatments. These soils had previously decomposed 22877, 18420, and 17964 pounds of $MgCO_3$ per acre, respectively, for loam, silty loam, and sandy loam. It would seem reasonable to assume that this heavy treatment and long-continued contact of carbonates and soil would have satisfied the requirements of physical absorption and that further decomposition should be attributed to chemical activities. The charges were subjected to moist contact treatment in Erlenmeyer flasks with (a) 2½ grams precipitated $MgCO_3$, (b) 3 grams of 100-mesh dolomite, and (c) a mixture of 2½ grams $MgCO_3$ and 2 grams $CaCO_3$. The CO_2 of the atmosphere of the sterile flasks was then drawn off and the closed flasks were permitted to remain under laboratory conditions. The rubber connections between the glass tubing and stopcocks were wired, after being immersed in hot paraffin, in order to insure long use without deterioration. At various intervals, the CO_2 of the atmosphere was drawn off and absorbed in soda-lime tubes. The figures of Table IV represent the CO_2 evolved.

These data show a continued evolution of CO_2 from these strongly alkaline sterile soils which had already effected a very excessive carbonate decomposition. The fact that for a long time these soils had been strongly alkaline and that they were also sterile would preclude the consideration of free organic acids as the cause of the decomposition of the carbonates. However, in view of the inherent oxidative power of soil as shown by Sullivan and Reid[1], Shreiner and Sullivan[2], and others, the entire CO_2 evolutions could not be attributed to the liberation of the CO_2 radical from the carbonates. Since the contact is to be continued for a longer period, the treated soils in the flasks were not available for determination of residual carbonates.

The next step was the elimination of organic matter from consideration as a possible source of the CO_2 liberated by contact treatment of soils and carbonates. A parallel series under conditions identical with those of the foregoing table contained a red clay secured six feet underground, and kaolin secured from a mineral supply house. Both materials showed absence of any soluble acids in distilled-water digestion. The decompositions resulting from these organic-matter-free substances are given in Table V.

These results agree with the observations of Morse and Curry[3] as to the ability of clay to decompose carbonates. The decompositions of both $CaCO_3$ and $MgCO_3$ effected by kaolin are not, however, in harmony with the observations of Dumont, quoted by Harris[4]. Dumont found that kaolin effected no decomposition of potassium carbonate. It appears to be

1. Jour. Ind. and Eng. Chem., Vol. 3, No. 1.
2. Bureau of Soils, Bul. 73.
3. N. H. Station, Report, 1907-1908, p. 271.
4. Mich. Station, Tech. Bul. 19, p. 14; Compt. Rend. l' Acad. d. Science, 1906, p. 34.

TABLE IV—*Decomposition of earthy carbonates by sterile alkaline soils, measured by determination of evolved gas*

Soil, 200 grams	Reaction to litmus and Veitch	Treatment	CO_2 evolved after	
			205 days $CaCO_3$ equivalent	545 days $CaCO_3$ equivalent
			Gms.	Gms.
Loam	Strongly alkaline	$MgCO_3$ [a]	1.0384	1.2082
Loam	Strongly alkaline	$MgCO_3$ and $CaCO_3$ [b]	.9932	1.1473
Loam	Strongly alkaline	Dolomite [c]	.4861	.6087
Silty loam	Strongly alkaline	$MgCO_3$ [a]	.8559	1.1646
Silty loam	Strongly alkaline	$MgCO_3$ and $CaCO_3$ [b]	.7604	1.0093
Silty loam	Strongly alkaline	Dolomite [c]	.5536	.6151
Sandy loam	Strongly alkaline	$MgCO_3$ [a]	.5309	.8128
Sandy loam	Strongly alkaline	$MgCO_3$ and $CaCO_3$ [b]	.4224	.6743
Sandv loam	Strongly alkaline	Dolomite [c]	.3941	Lost

a, 2½ gms.; b, 2½ gms. and 2 gms.; c, 3 gms.

TABLE V—*Decomposition of earthy carbonates by sterile organic-matter-free hydrated silicates*

Substance, 200 grams	Reaction of distilled water extract	Treatment	CO_2 evolved after	
			205 days $CaCO_3$ equivalent	545 days $CaCO_3$ equivalent
			Gms.	Gms.
Red clay	Very slightly alkaline	$MgCO_3$[a]	1.1297	1.2538
Red clay	Very slightly alkaline	$MgCO_3$ and $CaCO_3$[b]	.9229	1.2476
Red clay	Very slightly alkaline	Dolomite[c]	.8013	.9194
Kaolin	Very slightly alkaline	$MgCO_3$[a]	.4107	.5537
Kaolin	Very slightly alkaline	$MgCO_3$ and $CaCO_3$[b]	.3450	.5034
Kaolin	Very slightly alkaline	Dolomite[c]	.3552	.5185

a, 2½ gms.; b, 2½ gms. and 2 gms.; c, 3 gms.

worthy of note that although not reacting with alkali carbonates until leached by acid, kaolin will react with the alkali earth bases during long periods in moist contact. This direct chemical reaction between the acid silicates and earthy carbonates took place under conditions which, originally, at least, bring the carbonate and silicate together in water solution devoid of CO_2 gas.

THE ACTIVITY OF SiO_2 AS AN ACID

The work was carried one step further by the introduction of pure SiO_2, under the same conditions of moist, sterile contact which existed in the two preceding studies. In this parallel, ½ mm sand, and the same ground to pass 100-mesh, was used, together with pulverized quartz. The amounts of CO_2 evolved as a result of the treatment are shown in Table VI.

TABLE VI—*Decomposition of earthy carbonates by moistened sterile sand and pulverized quartz*

Substance, 200 grams	Treatment*	CO_2 evolved after	
		205 days, $CaCO_3$ equivalent	545 days, $CaCO_3$ equivalent
		Gms.	Gms.
Sand, ½ mm mesh	Precipitated $MgCO_3$	.0902	.1382
Sand, ½ mm mesh	Precipitated $MgCO_3$ and $CaCO_3$	.1225	.2291
Sand, ½ mm mesh	Dolomite	.1141	.1497
Fine sand, 100 mesh	Precipitated $MgCO_3$	.2272	.3277
Fine sand, 100 mesh	Precipitated $MgCO_3$ and $CaCO_3$	.2072	.3803
Fine sand, 100 mesh	Dolomite	.0952	.1765
Ground quartz	Precipitated $MgCO_3$	.5155	.8157
Ground quartz	Precipitated $MgCO_3$ and $CaCO_3$	.2357	.3256
Ground quartz	Dolomite	.2238	3697

*Amounts same as in Tables IV and V.

As would be expected, the influence of fineness of the silica on its solubility is indicated by the greater decomposition of the carbonates by the silt. The writer was induced to test for this possible quantitative reaction because of the well-known formation of magnesium silicate where evaporations of $MgCl_2$ and SiO_2 are heated too high, in the process of dehydrating silica. The decomposition of carbonates at room temperature was checked by boiling $CaCO_3$ and $MgCO_3$ separately with both pulverized quartz and finely ground rutile. The decompositions effected by 30 minutes' boiling are given in terms of grams of $CaCO_3$ (Table VII).

The decomposition of $CaCO_3$ and $MgCO_3$ by pulverized quartz was also accomplished in the procedure of evaporation given later in this bulletin, and, in less degree, in the use of the method of Tacke.

These data are confirmatory of the belief of Morey[1], who wrote, "Indeed, there is ground for the belief that silicic acid is considerably strong-

1. Jour. Am. Chem. Soc., 36, No. 2, p. 216.

er than has been supposed." From the results of the two preceding tables, it is easy to conceive of an appreciable decomposition of earthy carbonates through the action of the relatively large amount of exceedingly finely divided hydrated silica which must be present as a result of the long-continued dissolving and precipitating of SiO_2 in soils. It is possible that, in many cases, the undesirable physical conditions of soil are due largely to the occurrence of excessive amounts of colloidal silica.

Hall and Morison[1], however, found a decided benefit was observed over a long-time period when an alkaline silicate (sodium) was applied to soil. The silica seemed to perform a well-defined function. Their work was planned so as to check the effect of the sodium of the treatments. (The sodium silicate would most probably hydrolyze, yielding NaOH and colloidal silica). Where lime is added in amounts sufficient both to meet lime requirements and to insure an excess of carbonate, which would be the more subject to action of carbonated water, any calcium silicate resulting from treatment would probably remain largely as such. However, in presence of carbonated water the lime-silica reaction is readily reversed.[2]

TABLE VII—*Decomposition of $CaCO_3$ and $MgCO_3$ by boiling with SiO_2 and TiO_2*

Substance, 20 grams	Treatment,* 2 grams	CO_2 evolved, terms of $CaCO_3$
		Gms
Ground quartz	Precipitated $CaCO_3$	.0230
Ground quartz	Precipitated $MgCO_3$	.0966
Ground rutile	Precipitated $CaCO_3$	.0165
Ground rutile	Precipitated $MgCO_3$	.0520

*Freed of hydrates by CO_2 treatments.

THE INFLUENCE OF CARBONIC ACID UPON ALKALI EARTH SILICATES

As bearing further upon this point, the reversal of the lime silica and magnesia-silica reactions was studied. From 6 to 8 hours' simultaneous extractions were made daily of 10-gram charges of serpentine and wollastonite, and these compared with extractions of native carbonates. Limestone, about 92 per cent, dolomite of approximately the same chemical equivalence, and 93 per cent magnesite were used. All substances passed through the 100-mesh sieve. The wollastonite and magnesite, however, appeared to be somewhat finer than the other substances. The substances were kept agitated by the current of CO_2, as far as possible, and the extracts were filtered and titrated. The residue from each extraction

1. Proc. Royal Soc., Ser. B, 77 (1906).
2. Since writing the above, the author has seen thriving crops of wheat growing in nutrient cultures of 1% silica gel—unpublished thesis, D. S. Jennings, Cornell University, 1915. See also, A. Gregoire, Bul. Soc. Chem. Belg., 25, 1911, No. 2, pp. 85-103.

TABLE VIII—*Reversal of lime-silica and magnesia-silica reactions by hydrolysis of native silicates in carbonated water—terms of $CaCO_3$, grams, room temperatures, atmospheric pressure*

Hours of passage of CO_2 through mixture	Limestone, 100-mesh, 10 grams	Wollastonite, 100-mesh, 10 grams	Dolomite, 100-mesh, 10 grams	Serpentine, 100-mesh, 10 grams	Magnesite, 100-mesh, 10 grams
1st day, 6 hours	.8500	1.0250	.4750	.1250	.5050
2nd day, 7 hours	.7500	.8850	.3100	.0725	.4500
3rd day, 6½ hours	.7500	.6800	.2950	.0475	.4350
4th day, 8 hours	.7555	.6000	.3000	.0275	.2700
5th day, 7 hours	.7450	.6100	.2800	.1400	.2800
6th day, 6 hours	.6800	.3450	.2100	.0500	.1850
Total days 6, total hours 40½	4.5300	4.1450	1.8700	.4625	2.1250
Correction for $CaCO_3$ impurities	......	.6740	......	.1870	......
$CaCO_3$ derived by hydrolysis	......	3.4710	......	.2755	......

was returned to its flask for extraction upon the following day. Carbonate determinations upon the native samples of wollastonite and serpentine gave 6.74 and 1.87 per cent of $CaCO_3$, respectively. Corrections for these amounts are made in the table, the corrected amounts showing alkalinity necessarily derived from hydrolysis of the silicates.

As observed in the previous tables, the reaction between magnesium carbonates and silica and siliceous compounds is more extensive than that between these substances and calcium carbonate. The reversal of the magnesia-silica reaction through hydrolysis, in the presence of CO_2 in solution, is correspondingly more difficult than that of the lime-silica compounds.

INFLUENCE OF HYDRATION OF SILICA UPON ITS REACTIONS WITH EARTHY CARBONATES

The first step in the study of the influence of hydration of silicates upon their activities was an attempt to eliminate organic matter from a strongly calcareous soil without resorting to heat of combustion sufficiently high to effect complete dehydration of the silicates.[1] The loam soil used had been in contact with a large excess of $CaCO_3$ for over a year. Gentle relay heatings of 200 grams of the soil were accomplished in platinum dishes in the open by the use of a current of oxygen. It is, of course, not certain that partial or complete dehydration did not result, though a comparison of the results of Tables IX and X would indicate that complete dehydration was not effected. Possibly a better method of elimination of organic matter is that used by Harris[2], who boiled soil with concentrated H_2SO_4 and then freed the soil of acid by washing and filtering. After the oxygen-combustion treatment, the soil was mixed moist with calcium and magnesium carbonates separately and placed in closed Erlenmeyers, as previously described. The CO_2 found in the atmosphere of the flask later is given in Table IX.

TABLE IX—*Action of calcareous soil upon earthy carbonates, after oxygen combustion to remove organic matter*

Soil, 200 grams	Treatment	CO_2 drawn off, terms of $CaCO_3$, grams, after	
		133 days	473 days
Alkaline loam.	Precipitated $MgCO_3$, 2½ gms	.2868	.4805
Alkaline loam.	Precipitated $CaCO_3$, 2 gms.	.0797	.1310

1. It should probably be emphasized that because of treatments given which would be expected to eliminate colloids, both organic and inorganic, it naturally follows that the continued activities are to be attributed to chemical reactions rather than to physical absorption.

2. Mich. Station, Tech. Bul. 19.

The data of Table IX demonstrate that the occurrence of an excess of calcium carbonate from previous treatment is not an absolute deterrent in the continued silica-lime and silica-magnesia reactions. That is, the decomposition of earthy carbonates continues long after the satisfying of the initial, or temporary, lime-requirement indication of the Veitch laboratory procedure. The presence of $CaCO_3$ seemed to have but little, if any, depressing effect upon the phenomenon of decomposition of $MgCO_3$. The effect of previously applied excessive treatments of $MgCO_3$ was also tried after dehydration of the soil by ignition. Another portion of the loam soil which had previously decomposed 22877 pounds per acre 3,500,000 of soil was subjected to white heat in the muffle furnace for 16 hours. The residues from 200-gram charges of the initially treated soil were then moistened and mixed with separate charges of "C. P." $CaCO_3$ and $MgCO_3$ in closed Erlenmeyer flasks. The activities between the ignited residues and the two carbonates are shown in Table X.

It should be emphasized that before ignition this last soil was free of carbonates, though strongly alkaline from excessive amounts of magnesium silicate formed from previous $MgCO_3$ treatments. In spite of this treatment the decomposition of $MgCO_3$ is still far in excess of that of $CaCO_3$. The 16-hour ignition would certainly have accomplished dehydration, and it is difficult to account for the CO_2 evolution except by assuming appreciable rehydration of the dehydrated silica. This excessive decomposition of $MgCO_3$ was then effected under a short-time period of evaporation of ignited calcareous silty loam and $MgCO_3$, which in this case was added in solution of carbonated water. Four 10-gram charges of the calcareous silty loam of Table I were ignited for 16 hours in a muffle furnace. After ignition two charges were analyzed for residual CO_2, together with 150 cc of boiled $MgCO_3$ solution as blanks. The other two charges were evaporated on the water bath with the same volume of $MgCO_3$, and residual CO_2 was then determined. The blank showed a $CaCO_3$ value of 1.8863 gram, while the evaporated charges gave but 1.6075 gram, a loss of .2788 gram. That the same result cannot be obtained in any marked degree from $CaCO_3$ will later be shown.

RECOVERY OF WATER BY DEHYDRATED SILICA

The ability of pure SiO_2 to become hydrated again after ignition was then studied by comparison of the action of 200 grams of opal, $SiO_2.nH_2O$, upon earthy carbonates with its activity subsequent to ignition in a muffle furnace for a period of 16 hours. A parallel of TiO_2 was also included, the only difference being an 8-hour ignition period for TiO_2 instead of one of 16 hours. The occurrence of rutile in soils has been shown to be almost universal[1]. Especially is it to be found in clays. For this reason it was included in the study.

From the data of Table XI it would appear that the recovery of hydration by TiO_2, upon contact with moisture after heating, is much less

1. Am. Jour. of Sc., Dec. 1891; Chem. News. 65. 65.

Table X—*Action of ignited residues of magnesian soils upon calcium and magnesium carbonates under moist contact*

Soil, 200 grams	Previous treatment	Present treatment	CO_2 evolved after	
			133 days $CaCO_3$ equivalent	473 days $CaCO_3$ equivalent
			Gms.	Gms.
Strongly alkaline carbonate-free loam	22877 lbs. per acre $MgCO_3$	$CaCO_3$ 2 gms.	.1545	.2232
Strongly alkaline carbonate-free loam	22877 lbs. per acre $MgCO_3$	$MgCO_3$ 2½ gms.	.2259	.3560

Table XI—*Decomposition of $CaCO_3$ and $MgCO_3$ by opal and rutile, before and after ignition of minerals*

Substance	Treatment	CO_2 evolved, terms of $CaCO_3$ grams after 133 days' contact		CO_2 evolved after 473 days' contact	
		Before ignition $CaCO_3$ equivalent	After ignition $CaCO_3$ equivalent	Before ignition $CaCO_3$ equivalent	After ignition $CaCO_3$ equiva'ent
		Gms.	Gms.	Gms.	Gms.
Opal, 200 grams...........	Precipitated $MgCO_3$ 2½ gms.	.0425	.0271	......	.1580
Opal, 200 grams	Precipitated $CaCO_3$ 2 gms.	.0523	.0264	.2371	.0470
Rutile, 300 grams	Precipitated $MgCO_3$ 2½ gms.	.1803	.0186[a]	.2708	.0602[b]
Rutile, 300 grams	Precipitated $CaCO_3$ 2 gms.	.0479	.0125[a]	.1221	.0787[b]

a. Total period of contact, 91 days.
b. Total period of contact, 431 days.

extensive than that effected by SiO_2. However, by reference to Table VI it will be seen that the decomposition of the carbonates by ground quartz is much greater than that effected by opal. Decomposition of carbonates produced by evaporation of $CaCO_3$ and $MgCO_3$ with equal quantities of quartz and opal seemed practically identical, when the decomposition was measured by determinations of residual carbonates.

CARBONATE DECOMPOSITIONS UNDER LABORATORY CONDITIONS SUFFICIENTLY FEASIBLE FOR ADOPTION AS A METHOD

The data offered demonstrate conclusively that after the elimination of biological influences and the removal of organic and inorganic colloidal matter, we secure a continued decomposition of earthy carbonates by alkaline soils under moist contact conditions at normal temperatures. This decomposition is shown to be very appreciable in the absence of any hydrated silicates. The problem then resolved itself into an investigation to determine a procedure which would permit the maximum activities between soils and soil component materials under laboratory conditions during a period of time consistent with analytical work. This seemed to necessitate the use of an excess of earthy carbonate reagents in solution. The quantitative procedure relied upon to determine the presence of a sufficient amount of lime salts in humid soils is the determination of carbonate present, by the estimation of carbonate CO_2. Excess of carbonates in soils is usually coincident with appreciable quantities of silicates of lime. Gaither[1] has shown that the presence of carbonates is always characterized by absence of soil acidity. Hence, when there is obtained an indication of soil acidity and also an indication of $CaCO_3$ in the same soil, it necessarily follows that one of the two procedures is erroneous. The old procedure for determining carbonates by boiling soil invariably gives indications of carbonates, though the soil may be devoid of them and possess a high lime requirement. It has been shown, however, that absence of carbonates does not necessarily mean that lime-loving plants may not flourish. An abundance of lime as silicates will function as does the lime of carbonate in promoting good crops of clover[2]. However, the presence of carbonates of lime, in more than mere traces attributable to laboratory error, is usually taken as evidence that the lime-combining power of the acid radicals contained in soil has been satisfied. It would thus seem that the condition most nearly in accord with actual practice would be to determine the residual calcium carbonate from a definite application of it to the soil, after the soil has fully performed its immediate function of decomposing the carbonate.

1. Jour. Ind. and Eng. Chem., Vol. 6, No. 12.
2. Jour. Ind. and Eng. Chem., Vol. 5, No. 2.

The method of adding lime in solution naturally appealed first as the most feasible and adaptable when large numbers of determinations are to be made. The use of an aliquot is decidedly more rapid and less subject to error than the use of individually weighed charges. Another reason which prompted the use of aliquots is the uncertain composition of the precipitated "C. P." carbonates. The occurrence of basic hydrates is almost a positive source of error in differential CO_2 work, and it is necessary to carbonate the "C. P." products before differences between their original and residual CO_2 contents may be taken as the true measure of lime reaction. In previous work, unpublished, while at the Pennsylvania Station, the writer had endeavored to modify the Veitch procedure by adding a definite excessive amount of lime water, and evaporating to dryness, after which this evaporated soil and lime mixture was kept in suspension in water through which CO_2 passed for various periods, with the object of carbonating the excess of lime and holding it in solution for titration, after filtration through disc filters.

Two objections arose in the procedure. Apparently the excess of CaO acted upon organic matter during the evaporation, and different periods of carbonated-water extraction yielded varying alkalinities up to amounts considerably in excess of the lime actually applied. This, of course, meant that although the soil acid substances combined with the lime, the products of the reaction, together with original lime silicates and other salts were again converted to carbonates through hydrolysis, effected by the carbonated water. It still seemed feasible, however, to bring dissolved lime into contact with the soil under conditions which would not effect hydrolysis of the silicates. The idea of adding the solutions of lime and magnesia to the soils follows the thought that no matter in what form we may apply these two bases to soil in practice, their continued chemical dissemination throughout the surface mass occurs as solutions of the carbonates in carbonated water. It is true, however, that maximum reaction between the earthy carbonates and the acid silicates cannot transpire under optimum conditions of moisture, approaching saturation, when the moisture is impregnated with CO_2. That this is true is evidenced by the fact that normal leachings of strong acid, rock-derived humid soils and subsoils are universally alkaline. However, such leachings might become acidified in some instances when passing through extensive deposits of such substances as ferrous and other sulphides. The reversal of the hydrolysis effected by carbonated water may be expected to transpire when there occur temperature increases and moisture decreases, or when the carbonate is in dilute solution with moisture less rich in CO_2. As bearing on the point of an excess of CO_2 preventing the maximum reaction between $CaCO_3$ in solution and acid soils, the following was done: Definite aliquots of partly saturated $CaCO_3$ solution were added to eight 10-gram charges of different soils, the lime requirement by the Veitch method being known of several of the samples. After standing for 1 hour with several gentle stirrings, the soils were filtered through Buchner funnels and washed with slightly carbonated water by gentle suction. The solutions were then titrated and found to be almost

identical in alkalinities to those of the original, in case of the acid soils, and slightly more alkaline for two alkaline soils. It appeared essential, therefore, to rid the solution of the excess of CO_2 gas in order to bring about the desired reactions. This would, of course, result in the precipitation of $CaCO_3$, which would preclude the direct titration feature.

There appears to be a question as to the existence of an acid carbonate of lime at the pressures which would be exerted in soils and upper subsoils. Cameron and Robinson[1] and Leather and Sen[2] offered data which tend to show that the compound $CaH_2(CO_3)_2$ does not exist at atmospheric pressure below 4½, while McCoy and Smith[3] and Keiser and McMaster[4] offer contrary data.[5] The existence of the acid salt appears to be exceedingly doubtful. For the sake of brevity, however, whenever the term "bicarbonate" is used in this paper, it is intended to convey the meaning of a definite amount of $CaCO_3$ in solution of large excess of CO_2.

REACTION OF SOIL AND $CaCO_3$ THROWN OUT OF CARBONATED WATER SOLUTION BY AGITATION AND SUCTION

The activity of $CaCO_3$ toward soil after its precipitation from carbonated water at room temperature was then tried. The plan was to measure the $CaCO_3$ content of a boiled aliquot and then to determine the residual $CaCO_3$ after contact of carbonate with soil for different periods. Duplicate aliquots of 150 cc $CaH_2(CO_3)_2$ were added to 10 grams of soil in 300-cc Erlenmeyer flasks. Suction of 4 inches was applied during a 30-minute period to throw the $CaCO_3$ from solution and displace the excess of CO_2. In one set, agitation and aspiration was then continued for 1 hour, and in another set for an overnight period. A third set was immediately evaporated to dryness. The residual $CaCO_3$ from these three treatments was then determined by the Tennessee Station method[6]. The results are recorded in Table XII.

The two procedures at room temperature proved ununiform and unsatisfactory. It appeared doubtful whether the atmospheric CO_2 could be completely liberated from the bicarbonate solution before the additions of acid to decompose the residual carbonate, under the conditions of volume and agitation. The necessary volume of $CaH_2(CO_3)_2$ to insure sufficient excess of $CaCO_3$ was too great to permit of the most efficient agitation. The results from the evaporation showed that the decompositions of carbonates at room temperature were certainly not the maxima. That the greater reaction resulting from evaporation could not be attributed to the effect of heat upon organic matter is shown by the difference in the case of the clay subsoil.

1. Jour. Phys. Chem., 1908, XII, 561.
2. Memoirs Dept. Agr., India, Chem. Series, Vol. 1, No. 7.
3. Jour. Am. Chem. Soc., April, 1911.
4. Jour. Am. Chem. Soc., 1908, 1714.
5. See also, Johnston, Jour. Am. Chem. Soc., vol. XXXVII, No. 9, Sept., 1915, and Stieglitz, Carnegie Inst. Publ., No. 107, 1909.
6. Jour. Ind. and Eng. Chem., March, 1915.

Table XII—*Comparison of decomposition of $CaCO_3$, when added in solution and thrown out by suction, with its action when thrown out of solution by evaporation—terms of N/20 acid of titration*

Soil No. 10-gm. charge	Type	Reaction	Blank—soil + $CaCO_3$	Residual CO_2, determined by liberation with H_3PO_4		
				After 1 hour's contact	Overnight contact	Immediate evaporation
			cc	cc	cc	cc
3459	Silty loam	Acid	31.2	29.35	34.45	22.95
3464	Clay	Acid	31.2	23.8	29.1	17.7
3460	Silty loam	Alkaline	31.2	45.9	50.8	33.9
3461	Sandy loam	Acid	31.2	50.8	37.3	23.5
				37.5	37.9	24.5

EFFECT OF PERIOD OF CONTACT OF SOIL AND $CaH_2(CO_3)_2$ SOLUTION BEFORE EVAPORATION

The effect of immediate evaporation, as compared to that after 3 hours' agitation with suction to remove the excess CO_2, was then determined. One hundred cc aliquot of $CaCO_3$ solution was used alone and also supplemented by .2 gram of "C. P." precipitated $CaCO_3$. Results are given in N/20 acid titration for CO_2, by the Amos procedure for the absorption of CO_2. The results of Table XIII do not show any increased $CaCO_3$ decomposition when the longer contact period is used prior to evaporation.

TABLE XIII—*Comparison between decomposition of $CaCO_3$ upon immediate evaporation and evaporation after* 3 *hours' agitation*

	Sandy loam		Silt loam	
	100 cc alone	100 cc plus .2 gm $CaCO_3$	100 cc alone	100 cc plus .2 gm. $CaCO_3$
Residual CO_2 from immediate evaporation—cc N/20 acid..	13.8	14.6	49.3	52.8
Evaporation after 3 hours' agitation—cc N/20 acid	14.3	15.4	50.4	52.0

The next comparison made was between determinations of the decomposition effected by evaporation and boiling for periods of 5 and 30 minutes without subsequent evaporation. These determinations are given in Table XIV.

In the case of the clay, sandy loam and silty loam, the evaporation appeared to give somewhat greater decomposition than 5 minutes' boiling; but the reverse occurred in the case of the swamp soil. This might be

TABLE XIV—*Comparisons between immediate evaporation of soil with* 100*cc $CaH_2(CO_3)_2$ and boiling* 5 *minutes and* 30 *minutes*

Soil		Reaction	Residual $CaCO_3$, by determination of CO_2, terms of N/20 acid		
Lab. No.	Type		After evaporation	After boiling 5 minutes	After boiling 30 minutes
			cc	cc	cc
3459	Siltv loam ...	Acid	20.9	23.5	14.9
3461	Sandy loam ..	Acid	23.5	25.3	21.1
3466	Swamp	Acid	6.6	4.4	1.7
3464	Clay	Acid	16.1	19.6	14.9
Average			16.8	18.2	13.2

readily attributed to the intervening factor of action of heat and carbonate upon organic matter. Ground quartz also effected a greater decomposition of carbonates when evaporated with them than when subjected to the shorter period of boiling. The continued boiling would undoubtedly involve the extensive decomposition of soil organic matter, thereby making the procedure undesirable. The effects of different periods of evaporation were then studied. Two soils were evaporated with carbonate solution in porcelain evaporating dishes, which require from 1½ to 2 hours for evaporation, and also in 150-cc Jena beakers. After 9 hours' evaporation the residue of soil and $CaCO_3$ had been reduced to a very thin paste in the beakers. It remained thus overnight before determination of residue $CaCO_3$. The estimations of residual carbonates are given in Table XV.

TABLE XV—*Effect of variation in period of evaporation*

	Loam, N/20 acid	Silt loam, N/20 acid
	cc	cc
1½ hour	14.3	19.95
9 hours plus overnight..	11.7	16.9

It thus appears that a great difference in time of contact in the laboratory affects to some degree the extent of the reaction between the carbonate and soils. Very little error can be expected, however, in the slight variation of time involved in laboratory procedure when porcelain evaporating ware is uniformly used. This was shown by the evaporation of a soil with 100 cc of $CaCO_3$ solution and the repetition of the treatment and two additional 100 cc aliquots. The residual CO_2 in the single evaporation gave a CO_2 titration of 15.9 cc N/20 acid, while the triple evaporation gave 56.3 cc, the blank on two aliquots being represented by 38 cc. The residual CO_2 after evaporation of a clay subsoil with 150 cc $CaH_2(CO_3)_2$ was then compared to that found after the addition of 150 cc of distilled water to the evaporated clay and a subsequent evaporation. The residual CO_2 determinations were practically identical. From this point, a definite-sized container, a 150-cc porcelain evaporating dish, was used. Time of contact at room temperature was also found to exert an influence when the Tacke method was used. Twenty grams of clay, .4 gram $CaCO_3$ and 60 cc of CO_2-free water were agitated for 3 hours, with 4 inches of vacuum. This treatment gave a lime requirement of .44 per cent, while a second 3 hours gave an additional requirement of .09 per cent. Evaporation of the same clay and determination of residual CO_2 gave .53 per cent. That the further contact of soil and $CaCO_3$ for a period of 3 hours after the determination at room temperature is made by the Tacke method results in a further evolution of CO_2 is also shown in Tables XXIII and XXIV.

A comparison was next made between partial and complete evaporation of the $CaCO_3$ aliquot in contact with soil, with the results shown in Table XVI. Residual CO_2 is given in terms of N/20 acid titration.

TABLE XVI—*Comparison of evaporation of soil and 100 cc $CaH_2(CO_3)_2$ to dryness, and evaporation to approximately 50 cc*

Treatment	Residual $CaCO_3$, by determination of CO_2, terms of N/20 acid				
	Silty loam	Sandy loam	Clay	Swamp	Average
	cc	cc	cc	cc	cc
Evaporation to dryness......	20.0	21.8	18.3	11.65	17.9
Evaporation to one-half original volume	21.1	21.3	16.75	10.6	17.4

The results of Table XVI indicate that it is unnecessary to evaporate to complete dryness, in order to obtain the maximum of reaction between soil and carbonate, and that a thin paste is permissable. This facilitates the removal of the evaporated soil to flasks by washing with CO_2-free distilled water, in the determination of residual carbonates. Simultaneous evaporations were next made, with and without stirring. Stirring was done about the time of the precipitation of the carbonate from solution by the increasing heat, and again at about 75-cc and 50-cc volumes.

TABLE XVII—*Comparison between stirring mixtures of soils and $CaH_2(CO_3)_2$ solution during evaporation and evaporation without stirring*

Treatment	Residual CO_2, terms of N/20 acid			
	Silty loam	Sandy loam	Clay	Average
	cc	cc	cc	cc
Stirring 3 times.....	19.2	21.0	15.1	18.4
No stirring	20.9	21.8	15.9	19.5

The results of Table XVII, though not greatly at variance, are consistently lower in the estimation of residual carbonates when stirring was done. In succeeding work the definite procedure as to size of evaporating dish, and the three stirrings during evaporation, was followed consistently.

ADDITIONAL POINTS CONSIDERED

The next point considered was the possible action of the excess of CO_2 in the carbonated water of the $CaCO_3$ solution upon the silicates of an acid soil during the brief contact of soil with solution before expulsion of excess of CO_2 by evaporation. For soils low in lime and other silicates, this point was touched upon by the comparison between immediate evapora-

tion and evaporation after 3 hours' shaking (Table XIII). In order to make conditions more severe, the following was done: Ten-gram charges of calcium silicate and calcium-magnesium silicate were evaporated with the $CaCO_3$ aliquots. The determinations of residual carbonates gave no indication of any increase of carbonates as a result of hydrolysis during the brief period of contact of silicates and bicarbonate solution before expulsion of the excess CO_2 gas by heat of evaporation.

The relative activities of the $CaCO_3$ of aliquot solutions when soil was added prior to and after precipitation of $CaCO_3$ from bicarbonate solution were also studied. Aliquots of calcium and magnesium bicarbonate were placed on the water bath and soil added after the expulsion of CO_2 had caused precipitation of the carbonates. The evaporations were then continued and residual carbonates determined. Simultaneous evaporations of the bicarbonate solution were made after the addition of soil charges at room temperature. No difference could be detected in residual carbonates as a result of the difference in the time of introducing soil into the bicarbonate aliquots, which emphasized the previous observations that the reaction between carbonates and the acid-reacting soil constituents takes place to maximum extent under conditions which effect solution of the carbonates in water comparatively free of CO_2. That is, the presence of excess of CO_2 will tend to hold the $CaCO_3$ in solution and hinder the maximum reaction of carbonate with acid salts of the soil, or else a secondary hydrolytic reaction will recover $CaCO_3$ after its previous decomposition and conversion to silicates.

Repetitions of evaporations with additional charges added with each evaporation gave an apparent continued, but not extensive, decomposition of $CaCO_3$, but marked continuation in the decomposition of $MgCO_3$. However, as previously stated, the same holds true with CO_2-free water treatments in the cold, in Tacke's method.

The effects of various excessive amounts of $CaCO_3$ and $MgCO_3$ were next studied. One-half-gram charges and 2-gram charges of the earth carbonates were evaporated with 10-gram charges of alkaline and acid soils, and residual CO_2 determinations made. The results showed slight, if any, tendency toward increase of carbonate of lime decomposition as a result of the use of the heavy charge. Charges as heavy as 2 grams are exceedingly difficult to determine with accuracy volumetrically, because of the influence of the vast amount of CO_2 upon the sensitiveness of the indicator. The use of excessive amounts of $MgCO_3$, however, appeared to increase appreciably the $MgCO_3$ decomposition. The repetition of the evaporation of soil and $MgCO_3$ also resulted in continued decomposition of $MgCO_3$ to a greater extent than was true of $CaCO_3$.

The addition of a sufficient amount of $CaCO_3$ to insure a constant supply of carbonates in solution fulfilled the requirements essential to maximum decomposition under reasonable conditions.

EFFECT OF SOURCE OF CARBONATES ON REACTION WITH SOIL AND ON SOLUBILITY UNDER DIFFERENT CONDITIONS

The accuracy of the determination of residual carbonates, especially by the volumetric method, is enhanced by the use of the smaller excesses of $CaCO_3$. The carbonate giving the greatest solubility from a definite weight would therefore be the most desirable. The "C. P." precipitated carbonate is more nearly comparable in fineness with the carbonate thrown out of $CaH_2(CO_3)_2$ than with the finely ground mineral carbonates. The relative CO_2-free water solubilities of 100-mesh limestone, dolomite, and magnesite of approximately 92 per cent $CaCO_3$ values were accordingly compared with "C. P." CO_2-treated precipitated carbonates. Two-gram charges of each carbonate, in duplicate, were digested with 200 cc of distilled water in 250-cc flasks, for 45 minutes, at 94° C., three agitations being given the solutions. They were then immediately filtered through triple fluted gravity filters, and duplicates of 100 cc titrated with N/20 acid, phenolphthalein being used as the first indicator. Methyl orange was then added, and the titration continued. As comparisons, the same procedure was followed with CO_2-free distilled water at 20° C. and .02056 normal H_2CO_3 at the same temperature.

The results of titration are given in Table XVIII. As would be expected, the more finely divided carbonates gave the greater total solubility under each of the three conditions. The $CaCO_3$ precipitated from the bicarbonate is exceedingly fine, and its use by means of aliquots of $CaCO_3$ would therefore give maximum requirements with minimum charges. This point was further tested by evaporation of the different carbonates of calcium and magnesium with two soils and with serpentine, which, considered as the acid salt of orthosilicic acid, would be expected to decompose carbonates. The greatest decompositions were effected by the precipitated carbonates of both calcium and magnesium.

RELATIONSHIP BETWEEN $CaCO_3$ AND $MgCO_3$ REQUIREMENTS OF SOILS

Data obtained in contact treatment over long periods at room temperature showed that the satisfying of a soil's requirement for lime did not preclude its further reaction with and decomposition of large amounts of magnesium carbonate. It also appeared that though both substances are capable of neutralizing the acidity of silicic acid, as well as that of acid silicates, during long periods of moist contact at ordinary temperatures, there appears to be no definite relationship between the amount of CO_2 given off from the two carbonates. Investigation was then made of the relation between the activities of the two carbonates under the conditions of the procedure proposed as a laboratory method for lime requirement.

A clay subsoil was treated with 100 cc of $MgCO_3$ and $CaCO_3$ solutions separately, and residual $CaCO_3$ equivalents determined after evaporation.

TABLE XVIII—*Solubilities of mineral and "C. P." carbonates in CO_2-free distilled water and in carbonated water under different digestion conditions, terms of N/20 acid*

2 gms. of substance	CO_2-free distilled water, 45 minutes at 94° C.			CO_2-free distilled water, 45 minutes at 20° C.			45 minutes N/.02056 H_2CO_3		
	Phenol-phthalein	Methyl orange	Total	Phenol-phthalein	Methyl orange	Total	Phenol-phthalein	Methyl orange	Total
	cc	cc	cc	cc	cc	cc	cc	cc	cc
Precipitated $CaCO_3$..	1.10	.85	1.95	.05	.80	.85	0	29.6	29.6
Precipitated $MgCO_3$.	.5	3.20	3.70	1.85	2.40	4.25	0	70.0	70.0
Limestone, 100-mesh.	.1	.95	1.05	.025	.725	.75	0	24.45	24.45
Dolomite, 100-mesh..	.15	1.10	1.25	.25	.75	1.00	0	11.2	11.2
Magnesite, 100-mesh.	.15	1.35	1.50	.175	.75	.925	0	11.45	11.45

The $CaCO_3$ decomposition was represented by .0720 gram from a treatment of .1011 gram, and the $MgCO_3$ by .1960 gram, 10-gram charges of clay being used in each instance.

This decomposition of $MgCO_3$ was in accord with the results obtained by simple long-continued contact treatments in the laboratory at room temperature. Treatments of four acid soils were then made by the Hutchinson-MacLennan process, $MgCO_3$ solution, as well as one of $CaCO_3$, being used. The results are given in Table XIX.

TABLE XIX—*Reaction between soils and $CaH_2(CO_3)_2$ and soils and $MgH_2(CO_3)_2$, terms of $CaCO_3$ extracted from the solution as in Hutchinson-MacLennan procedure*

Soils	Loam	Silty loam	Sandy loam	Sandy loam	Average
Gms. $CaCO_3$ extracted	.0078	.0073	.0173	.0071	.0099
Gms. $MgCO_3$ extracted	.0375	.0275	.0575	.0325	.0388

From the data of Table XIX it would appear that in every instance where soil is afforded opportunity to effect decomposition of the two carbonates, the magnesium salt is far more extensively decomposed.

That the presence of an excess of $CaCO_3$, applied a long time previously, does not prevent the further decomposition of $MgCO_3$ under laboratory conditions was determined by the evaporation of two strongly calcareous soils with $MgCO_3$, which treatment resulted in the decomposition of appreciable amounts of $MgCO_3$. This observation was again made with a weaker solution of $MgCO_3$. The magnesium carbonate solution was diluted ten times to make it approximate more nearly the 90 per cent saturated $CaCO_3$ solution. Twenty-gram charges of the calcareous loam and silty loam of Table I were then added to 150 cc of boiled $CaCO_3$ and run as a blank, while another 150-cc portion of $CaCO_3$ was evaporated with the soil. The blank was then compared to the evaporated residue for residual carbonates. The same treatment was duplicated, with $MgCO_3$. The relative activities of the two carbonates upon the calcareous soils are given in Table XX.

TABLE XX—*Comparison between evaporations of calcareous soils with $CaH_2(CO_3)_2$ and diluted $MgH_2(CO_3)_2$, terms of N/20 acid in CO_2 determinations*

	$CaCO_3$		$MgCO_3$	
	Loam	Silty loam	Loam	Silty loam
	cc	cc	cc	cc
Blank	46.6	39.3	54.4	58.5
After evaporation	44.9	38.6	44.7	34.3
Difference	1.7	.7	9.7	24.2

The close agreements between blanks and treatments in the $CaCO_3$ treatments, and the wide difference between the $MgCO_3$ blank and treatment could not be attributed to the difference in the solubilities of the two carbonates shown in Table XVIII. They undoubtedly prove that $CaCO_3$ and $MgCO_3$ have different relationships from those which would be indicated definitely by solubilities, fineness, or molecular weight, in the extent of their requirements by soils.

In view of this disparity between relations of $CaCO_3$ and $MgCO_3$ as influenced by their solubilities, but more particularly by the extensive affinity of MgO for SiO_2 and its compounds, it would appear fallacious in the extreme to endeavor to interpret a soil's requirement for one carbonate by the chemical equivalence of any one carbonate to that of any other. The fact is thus emphasized that the correct procedure to follow in determination of $CaCO_3$ requirement would involve the use of that same carbonate.

A study was then undertaken to determine whether the magnesium carbonate decomposition eliminates a soil's ability to decompose calcium carbonate. The three $MgCO_3$-treated soils of Table I were next evaporated with $CaCO_3$ solution. Ten-gram charges of soil and 150-cc aliquots of the solution were used. Determinations of residual carbonates after evaporation showed that the alkaline magnesian soils possessed very limited, if any, ability to decompose $CaCO_3$ after they had already accomplished a heavy dissipation of CO_2 from previously applied $MgCO_3$.

Thus we find that $MgCO_3$ will satisfy a soil's requirement for lime, but that the satisfying of a soil's requirement for lime, by long-continued contact with $CaCO_3$ does not inhibit the excessive decomposition of added $MgCO_3$ under laboratory treatment. Not only is this true of normal calcareous soils, but it is also true of soils which have been ignited with an excess of $CaCO_3$.

EFFECT OF THE PRESENCE OF ALKALI CARBONATES UPON THE DECOMPOSITION OF MAGNESIUM CARBONATES BY SOIL

The influence of the presence of sodium and potassium carbonates upon the decomposition of $MgCO_3$ was then studied. Twenty-gram charges of the calcareous loam and the silty loam of Table I were evaporated with 50-cc aliquots of Na_2CO_3 and K_2CO_3 separately, the aliquots representing .5 gram of the alkali carbonates. One hundred and fifty cc aliquots of $MgCO_3$ solution were added and evaporated, while the blank was evaporated again with the same volume of distilled water. Determinations of residual carbonates were then made upon the treated soils and compared with the blank plus 150 cc of the boiled magnesium carbonate solution. The alkali carbonates of course attacked the organic matter of the soil, but this was accounted for by the blanks. The decomposition of magnesium carbonate shown in Table XXI resulted, then, after calcium carbonate had been in contact with the soils for one year, and after evaporation with both sodium and potassium carbonates.

TABLE XXI—*Decomposition of $MgCO_3$ from $MgH_2(CO_3)_2$ by calcareous soils, after preliminary evaporation with Na_2CO_3 and K_2CO_3*

Loam	$CaCO_3$ value	Silty loam	$CaCO_3$ value
	Gms		Gms.
Blank soil evaporated with Na_2CO_3 solution and 150 cc of boiled $MgH_2(CO_3)_2$ solution added	1.6850	Blank soil evaporated with Na_2CO_3 solution and 150 cc of boiled $MgH_2(CO_3)_2$ solution added	1.6500
Soil evaporated with Na_2CO_3 and 150 cc $MgH_2(CO_3)_2$ solution	1.2625	Soil evaporated with Na_2CO_3 and 150 cc $MgH_2(CO_3)_2$ solution.	1.2375
Decomposed by evaporation	.4225	Decomposed by evaporation	.4125
Blank soil evaporated with K_2CO_3 solution and 150 cc of boiled $MgH_2(CO_3)_2$ solution added	1.6825	Blank soil evaporated with K_2CO_3 solution and 150 cc of boiled $MgH_2(CO_3)_2$ solution	1.6725
Soil evaporated with K_2CO_3 and 150 cc of $MgH_2(CO_3)_2$ solution	1.2225	Soil evaporated with K_2CO_3 and 150 cc of $MgH_2(CO_3)_2$ solution	1.2350
Decomposed by evaporation	.4600	Decomposed by evaporation	.4375
Soil, plus boiled $MgH_2(CO_3)_2$ solution without alkali carbonates	1.3540	Soil, plus boiled $MgH_2(CO_3)_2$ solution without alkali carbonates	1.3510
Soil after evaporation with $MgH_2(CO_3)_2$ solution	.9096	Soil after evaporation with $MgH_2(CO_3)_2$ solution	.9650
Decomposed by evaporation	.4444	Decomposed by evaporation	.3860

It would thus appear that the addition of precipitated $MgCO_3$ or burnt magnesia to *alkali* soils would result in the decomposition of $MgCO_3$.

It further appears that the combined presence of calcium, sodium and potassium carbonates is not necessarily inhibitory of the decomposition of the precipitated carbonate of magnesium.

EFFECT OF ALKALI TREATMENT UPON THE ABILITY OF RUTILE TO DECOMPOSE $MgCO_3$

Satisfying of the alkali requirement of titanium oxide does not prevent the continued reaction between TiO_2 and $MgCO_3$. Rutile was treated with strong NaOH for 10 days and then freed of the alkali, after which treatment it was subjected to contact with $MgCO_3$ at room temperature. One hundred grams of rutile was moistened and mixed with 1 gram of precipitated $MgCO_3$. After 330 days' contact of rutile and carbonate the CO_2 gas was drawn off and was found to represent an equivalent of .1484 gram of $CaCO_3$.

COMPARISON OF PROPOSED METHOD WITH THE PROCEDURE OF HUTCHINSON AND MacLENNAN

The method proposed in this bulletin was then compared with the method of Hutchinson and MacLennan. Two strengths of $CaH_2(CO_3)_2$ were used. One hundred cc of .1011-gram $CaCO_3$ equivalent was used and also the same volume after dilution by the addition of 50 cc of carbonated water. The differences between the amounts of $CaCO_3$ used by the soils when the carbonate was offered in solution of CO_2, and in water free of CO_2 by evaporation, are shown in Table XXII.

Inspection of Table XXII shows that a greater decomposition is effected in every case where the evaporation is made, above that effected by agitation with the bicarbonate solution.

RELATION OF THE INDICATIONS OF THE TWO METHODS TO THOSE OBTAINED BY THE VEITCH METHOD

The soils of Table XXII were then treated with the respective $CaCO_3$ indications of the two methods and carried out from that point as Veitch-method determinations. In addition to the indicated amounts of $CaCO_3$ solution, two drops of saturated lime water were added to each treatment in order to insure a slight excess and to allow for a plus or minus analytical error. After evaporation with the amounts of $CaCO_3$ indicated by the respective methods the soils were run as blank Veitch determinations. In each instance the Hutchinson-MacLennan-method indication plus lime water failed to show alkalinity by the Veitch test. On the other hand, every soil treated with the indication of the proposed method plus two drops of lime water gave an alkaline Veitch test.

These tests demonstrate that the Hutchinson-MacLennan method falls short of satisfying the Veitch requirement, while the proposed method

TABLE XXII—*Comparison of proposed method with the Hutchinson-MacLennan method, and the latter when modified by the addition of 50 cc of carbonated water*

Soil		Reaction	Hutchinson-MacLennan method				Hutchinson-MacLennan method modified				Proposed method			
Lab. No.	Type		$CaCO_3$ added in solution	$CaCO_3$ found in filtrate	$CaCO_3$ utilized	$CaCO_3$ requirement lbs per acre 2,000,000	$CaCO_3$ added in solution	$CaCO_3$ found in filtrate	$CaCO_3$ utilized	$CaCO_3$ requirement lb per acre 2,000,000	$CaCO_3$ added in solution	Residual $CaCO_3$	$CaCO_3$ utilized	$CaCO_3$ requirement lbs. per acre 2,000,000
			Gms.	Gms.	Gms.	Lbs.	Gms.	Gms.	Gms.	Lbs.	Gms.	Gms.	Gms.	Lbs.
3455	Clay loam....	Acid...	.1011	.0933	.0078	1560	.1011	.0921	.0090	1800	.1011	.0750	.0261	5220
3458	Silty loam ...	Acid...	.1011	.0938	.0073	1460	.1011	.0938	.0073	1460	.1011	.0730	.0281	5620
3459	Silty loam ...	Acid...	.1011	.0828	.0183	3660	.1011	.0893	.0118	2360	.1011	.0553	.0458	9160
3466	Swamp	Acid...	.1011	.0490	.0521	10220	.1011	.0583	.0428	8560	.1011	.0240	.0771	15420
3462	Loam	Acid...	.1011	.0838	.0173	3460	.1011	.0888	.0123	2460	.1011	.0690	.0321	6420
3464	Clay	Acid...	.1011	.0660	.0351	7020	.1011	.0693	.0318	6360	.1011	.0291	.0720	14400
3463	Sandy loam ..	Acid...	.1011	.0940	.0071	1420	.1011	.0985	.0026	520	.1011	.0935	.0076	1520
3461	Sandy loam ..	Acid...	.1011	.0922	.0089	1780	.1011	.0958	.0053	1060	.1011	.0820	.0191	3820
3465	Loam	Acid...	.1011	.0745	.0266	5320	.1011	.0798	.0213	4260	.1011	.0480	.0531	10620
	Average		.1011	.0810	.0201	3989	.1011	.0851	.0160	3204	.1011	.0610	.0401	8002

meets the Veitch requirement in every instance. As to the relation of the results to those of the Veitch indication, further work is offered in Table XXIII.

Not only does the Hutchinson-MacLennan method fail to produce the decompositions equivalent to those effected by the Veitch or the proposed method, but the carbonated water solvent depresses the reaction and gives less carbonate decomposition than is effected by agitation with $CaCO_3$ in CO_2-free water for the same period at room temperature, as per the Tacke procedure. That this is true is shown by the data of Table XXIII.

Gardner and Brown[1], after applying the exact amounts indicated by the Veitch method, and then growing two crops of clover, found 28 per cent of the original Veitch as the residual lime requirement eight months after treatment. Hutchinson and MacLennan[2] found .05 per cent requirement by their method upon a soil which had one year previously received

TABLE XXIII—*Comparison of the proposed method with the methods of Veitch, Tacke, and Hutchinson and MacLennan*

Soil	$CaCO_3$ per 2,000,000 lbs. of soil			
	Proposed	Veitch	Tacke	Hutchinson-MacLennan
	Lbs.	Lbs.	Lbs.	Lbs.
Clay subsoil	14400	7420	8850[a]	7020
Swamp silt	15420	11428	19900[b]	10220
River-bottom silt-clay loam	10620	7536	9850[c]	5320
Average	13480	8794	12866	7520

Three hours additional: a, 1750; b, 4850; c, 3800.

.36 per cent $CaCO_3$, although its original lime requirement, according to their method, was but .26 per cent; and in another instance, .02 per cent requirement after an application of .54 per cent to a soil showing an original need of but .43 per cent by their method. In other words, after adding an average excess of 33 per cent above their method's indications, and permitting contact for one year without cropping, they found that both soils were still acid to their method, which when run at the end of the year showed that their original lime-requirement indications had been but 56 per cent of the final indications.

Tests as to the attaining of maximum decomposition of $CaCO_3$ by the Hutchinson-MacLennan method were then made by the use of three different charges of a silty soil and an acid clay subsoil. The soils were filtered by gentle suction through Buchner funnels, and a 5/6 aliquot of each was titrated. The residues were then washed twice with rapid

1. Pa. Station, Report, 1910-11, pp. 25-76.
2. Chem. News, 110, No. 2854, 1914.

TABLE XXIV—*Effect of variations in soil charges in the Hutchinson-MacLennan method and continued reaction of the method's soil residues upon further additions of $CaCO_3$ solution—constant volumes of $CaCO_3$ solution used throughout*

Charge	$CaCO_3$ removed from solution by soil in the Hutchinson-MacLennan method						$CaCO_3$ decomposed by subsequent contact of residues with $CaCO_3$ in CO_2-free water					
	5 gm.		10 gm.		20 gm.		5 gm.		10 gm.		20 gm.	
	Gms.	Per ct.	Gms.	Per ct.	Gms.	Per ct.	Gms.	Per ct.	Gms.	Per ct.	Gms.	Per ct.
Silty loam ..	.0093	.186	.0063	.063	.0145	.073	.0125	.250	.0220	.220	.0310	.155
Clay subsoil	.0244	.488	.0345	.345	.0615	.308	.0185	.370	.0220	.220	.0340	.170

passages of carbonated water, then with distilled water, after which they were agitated for 3 hours with CO_2-free distilled water and .4 gram of precipitated carbonate. The agitations with both carbonated water solution and CO_2-free water solution were uniformly and efficiently made by mechanical shaking. The results are given in Table XXIV.

These data show that not only does the Hutchinson-MacLennan procedure fail to effect maximum decomposition of carbonates, but the reaction is not in proportion to the charge of soil used.

In proposing the method described at the conclusion of this bulletin, the writer believes that the conditions of the procedure effect a complete satisfying of the *temporary lime requirement* of soils. That the determinations by the Veitch method, after previous Veitch-indication treatments had been applied, showed an extensive additional lime requirement in the work of Gardner and Brown[1] and in that reported in this bulletin would be justification for the higher results by the proposed method. Opportunity has not yet been afforded for the testing of lime requirements after treatments with the indications of this method, as was done in the case of the Veitch studies. The laboratory studies would leave no doubt, however, that the same observations would follow the use of this method's indications as to additional amounts necessary to meet a soil's *continuous lime requirement*.

The proposed method is intended to supply a simple procedure which will permit the satisfying of the maximum immediate lime requirement of acid silicates and silicic acid, the principal causes of lime requirement to be found in rock-derived soils. The method of determining lime requirement is believed to be an improvement upon the Veitch method, in that it does not involve so tedious manipulation and in that it eliminates the heating of soil organic matter with the more active hydrate of lime.

The repetition of the evaporation in the procedure gives practically no action between soil and calcium carbonate, while continuation of the Tacke procedure gives a large proportion of the original indication of the method. Such being the case, the residual carbonate determined in the Süchting method would necessarily be greater than the amount which the soil would decompose if it had further opportunity for contact at normal temperature, which would mean lower results than the maxima.

RELATION BETWEEN LABORATORY AND FIELD LIME REQUIREMENTS

The writer believes that the relationship between the laboratory determinations and actual crop needs is a phase of the subject to be tested by extensive field work, under various conditions of climate, soil-type, and fertility. After determining the maximum decomposition of $CaCO_3$ under laboratory conditions, that is, the maximum temporary lime requirement, we could then determine for various types the factors which would prove most desirable in practice. And under practical conditions, where loss by

1. Pa. Station, Report, 1910-11, pp. 25-76.

leaching is a factor, the results should be based upon plant response for more than one season. For though the application of indications of two methods giving appreciable differences might give comparable results in the crop increase of the first season, the response during the second and succeeding seasons might be considerably greater from the larger treatment.

The continuous lime requirement observed in laboratory and pot studies appears to bear but little if any relation to the practice of liming, except as to the influence of the lime-silica reaction upon the conservation of lime in the soil. However, the continued decomposition of carbonates when present in excess under laboratory conditions and in basket work is entirely in harmony with observations in practice. That this is true is shown by analyses of the burnt lime and limestone plots of the Pennsylvania Station General Fertilizer Experiments, where about 35 per cent of the lime accumulated from treatment is now to be found as silicates.[1]

THE OCCURRENCE OF SOIL ACIDITY IN FIELD AND LABORATORY EXPERIMENTS

The studies here reported, and other observations in kindred experiments, have led the writer to adhere to certain pronounced views as to the existence of, and reasons for, soil acidity. The writer has had no experience in the investigation of peat soils, and the discussion following is therefore based upon soils of mineral origin.

By the term "soil acidity" it is intended to refer to a soil's ability to decompose calcium carbonate. First, it must be emphasized *that in uncarbonated H_2O solution, SiO_2 proves to be a stronger acid radical than CO_2 of earthy carbonates. The reversal of conditions is effected when there is present an excess of CO_2 gas.* This would be expected as sequence of mass action. It is probably true, as indicated by data given, that both of these conditions actually exist at different times under field conditions. At times, a soil solution near the surface may be heavily charged with CO_2 gas, while at other times it may be almost free therefrom.

Silica precipitated from soil solutions is considerably finer and more soluble than finely ground quartz, which has been shown, in this bulletin, to react appreciably with alkali-earth carbonates, and we would expect it to give more extensive decomposition of $CaCO_3$ than is effected by silt, even as ground quartz is more active upon the carbonate than is fine sand, which in turn is more active than coarse sand. The methods which direct the use of calcium carbonate in laboratory treatments of soils are influenced by this lime-silica reaction. But those methods which bring salts of the stronger acids into contact with silicic acid do not involve the replacement of the strong acid radicals of the neutral salts by that of silicic acid; that is, calcium carbonate is decomposed by silicic acid, H_2SiO_3, but the solutions of nitrates are not affected by contact with finely ground moist SiO_2.

It is true that there is vast difference between soils in the field and the same soils in the air-dry laboratory condition. In laboratory studies

1. Pa. Station, Report, 1911-1912, p. 640.

of soil acidity, however, consideration of this difference in many cases appears to be minimized or entirely disregarded. Leaching studies of field soils, however, emphasize this difference. A soil may be acid to litmus in both field and laboratory, but its natural solution, as judged by its leachings, may be distinctly alkaline. Its solution in CO_2-free water in the laboratory will usually be neutral, but if the laboratory solution be made with carbonated water it will generally be alkaline. Though the extract be alkaline in reaction, the alkalinity may be attributed more particularly to acid salts, so regarded when calcium and magnesium carbonates in solution are considered as bicarbonates, rather than as carbonates in solution. The extract will of course in some cases contain some carbonates of sodium and potassium. The normal alkali-earth silicates of calcium are the most readily hydrolyzed, and $CaCO_3$ predominates in the alkaline leachings of an acid soil well supplied with calcium silicate. Thus we have an acid, a weak organic acid, H_2CO_3, removing an alkaline-reacting extract and leaving a soil with a greater tendency to absorb lime. As bearing on this point, the writer extracted a charge of an acid sandy clay soil with carbonated water. The extract was of course distinctly alkaline, but lime requirements made upon the soil by the proposed method, before and after extraction, showed that the soil's lime requirement had increased after extraction almost sufficiently to account for the alkalinity of the filtered carbonated water extract. Likewise, when we apply ammonium sulphate to soil, the resultant liberated acid radical extracts bases from the normal silicates, and increases the occurrence of acid silicates, which means increase in lime requirement. Possibly the use of acid phosphate results in the utilization of the bases of soil silicates and a consequent increase in lime requirement. This conclusion was drawn by Gardner and Brown[1] with reference to the dissolved-bone-treated plots of the Pennsylvania Station.[2]

It has been held that soil acidity is due to the existence in the soil of free organic and mineral acids. "Humic acid" is the collective, though indefinite, term ordinarily used for the supposed organic acids. That we do have free mineral acid—silicic acid—in soil, is true. It has been shown in this bulletin that this acid effects appreciable and long-continued decomposition of $CaCO_3$, and excessive decomposition of $MgCO_3$, and that its acid salts—clays—are even more active than the relatively insoluble acid itself.[3] But the assumption that organic acids other than H_2CO_3 exist in soils more than a brief transitory period is unproved. Free organic and mineral acids would be subjected either to contact with a soil solution of $CaCO_3$, $MgCO_3$, and other silicate-derived carbonates, or they would come into contact with calcium and magnesium, and possibly other silicates, upon which citric, oxalic, and such weak organic acids react. As showing that nitric and organic acids do become neutralized as they are formed from nitrification and fermentation in soils, the following

1. Pa. Station, Report, 1910-11, pp. 25-76.
2. See also Conner, Jour. Ind. and Eng. Chem., Jan., 1916.
3. The purely physical absorptive properties of soil colloids are admittedly extensive, but after the elimination of these substances we have observed a continued decomposition of $CaCO_3$, making it necessary to attribute to chemical activities at least a part of the reaction noted.

was done: Five-cc and ten-cc aliquots of both HNO_3 and $C_2H_2O_4$, N/20, were placed separately in 250 cc of freshly distilled water, containing 10 grams of *acid clay* subsoil, and a current of CO_2 was passed through the mixtures for 4 hours. The mixtures were then immediately filtered separately and each extract was found to be distinctly alkaline, requiring as much as 5 cc N/20 acid to neutralize. Checks run simultaneously with CO_2-free distilled water gave very slightly alkaline or neutral solutions for both organic and mineral acid treatments. Ten-gram charges of the same acid soil, in duplicate, were then shaken gently overnight with 12½ cc of N/2 HNO_3, diluted to 125 cc, filtered, washed, and extract titrated. Nearly 8 cc of the N/2 acid had been used by the acid soil. Such an amount would represent the nitrification to HNO_3, or over 11000 pounds of N per 2,000,000 pounds of soil, and the conversion of the acid to neutral salts. The same treatment with oxalic acid utilized 9.6 cc of N/2 acid, while 10.5 cc of the trivalent citric acid was neutralized. It is thus plain that even without the soluble bicarbonates, which are present when there is an abundance of CO_2, the readily attacked silicates would prevent the continued occurrence of any free organic or mineral acids, excepting carbonic and silicic. Thus, in a soil we may have not only neutral salts of mineral acids, more particularly HNO_3, but also organic acid and neutral salts, especially of calcium.

That organic acids are products of green manuring and normal soil fermentation is undoubtedly true, but, were the generated acids not quickly neutralized by the alkaline soil solution derived from calcium and magnesium and other silicates, we would have characteristic acidity in those soils which have received frequent and heavy applications of barnyard manure. But, instead of increasing the soil acidity, the use of manure tends to maintain near-alkaline conditions to an extent which could not be attributed to the included comparatively small amount of organic lime and other bases. That the lime of such manure treatments is readily available, and that it is conserved and repeatedly used as a neutralizer in the cycle which it follows, is shown most admirably by Hall in his treatise, "Some secondary actions of manures upon soils." The conservation of lime from treatments of barnyard manure is also emphasized by results obtained by the writer on the manure plots of the Pennsylvania Station.[1]

As a further convincing argument that so-called free "humic acid" is not to be considered as a reason, except colloidal, for soil acidity, a subsoil is usually more acid than its organic-matter-containing surface soil, where undisintegrated rock particles and close proximity of original carbonate rock do not interfere. Sandy soils and those soils especially low in their lime requirements usually contain relatively small amounts of clay. Conversely, a heavy clay soil is usually acid and high in its lime requirement, even when very low in organic matter. In other words, excessive soil acidity, as measured by the ability of a soil to effect decomposition of $CaCO_3$, is coincident with occurrences of clay, or acid silicates.

1. Pa. Station, Report, 1911-1912, p. 640.

The existence of determinable temporary soil acidity or lime requirement, and the presence of carbonate of lime as a solid mineral in soil, are not compatible, save in such cases as glacial clay. However, as previously stated, a soil may be strongly acid in its effect upon carbonate of lime, when following the various procedures offered for determining the extent of this acidity, and yet its extract, or leaching, will often be strongly alkaline and impregnated with $CaCO_3$. The writer has analyzed many hundreds of surface and deep waters, and many of them from sections considered to be devoid of any native carbonate rocks, but he has never found an earth water which was not distinctly alkaline, save in two instances of waters which flowed through very extensive swamps. Unusual occurrences of excessive mineral sulphides might, however, in some instances overcome this alkalinity. In some sections such alkalinity must in the main be derived from the hydrolyzation of soil silicates. As bearing on this point, drainage waters collected in leaching experiments at this Station are invariably alkaline, though coming from acid soils, devoid of carbonates. This alkalinity is sometimes increased by the passage of drainage waters through additional depths, up to 5 feet, of strongly acid clay subsoil. The alkalinity of leachings varies appreciably. At times leachings are heavily impregnated with $CaCO_3$, and at other times they contain a preponderance of alkali carbonates. This is readily shown by boiling the leachings at various times and making alkalinity determinations before and after the removal of precipitated $CaCO_3$. It might be expected that during the winter the water of lower temperature would be more heavily charged with CO_2, and having less crop growth to assimilate the dissolved $CaCO_3$, the leachings might consequently be more alkaline than under conditions of higher temperature and greater plant growth. The increase of temperature during the growing season would tend to expel the gas from solution near the surface, thus giving a weaker solvent, though in the soil atmosphere there would probably be greater quantities of CO_2 than would be found under colder conditions. The reactions involved in the decomposition of applied carbonate and the hydrolysis of silicates and leaching of bases may be shown with ease in the laboratory. Untreated, highly acid clay subsoil, and the same after treatment and evaporation with a little less $CaCO_3$ than that represented by its lime requirement, may be used. Both of the carbonate-free soils are then extracted for a few hours with carbonated water. Thus we find the carbonate is first decomposed by its reaction with both H_2SiO_3 and acid silicates in the absence of dissolved CO_2, and then the reaction is reversed in the presence of carbonated water. This may be quantitatively shown by the titration of the easily filtered carbonated water solution. Gentle suction through a Buchner funnel gives a quick filtration. This explains, in part, why maximum decomposition of added carbonates in solution is not obtained in the Hutchinson-MacLennan method. Either a forcing back of the lime-silica reaction is effected by the excess of CO_2 or else a secondary hydrolysis and recarbonation reaction takes place.

Since we admit that the soil's solution is the medium through which a plant absorbs its mineral supply, we are compelled to conclude that a plant's source of nutrition is almost always alkaline, but of varying degrees

of alkalinity. Thus we have lime-loving plants which do not thrive, *not because their nutrient solutions are acid, but because the available solutions are not sufficiently concentrated in their $CaCO_3$ content,* or possibly in neutral salts of root-formed acids which act directly upon the bases of unhydrolyzed silicates. It is conceivable that rapidly growing plants would extract lime and also other bases from a soil solution more rapidly than the soil moisture could effect the hydrolysis of the silicates, from which an acid soil principally derives the bases which are offered to the plants. This would of course give a soil solution approaching very nearly to neutrality. The soil solution would not become acid, however, even under this condition, for any nitric or organic acid formed after removal of bases from solution by plants would be quickly neutralized through direct reaction of acids upon the various bases of the silicates.

A point in field practice readily illustrates the foregoing hypothesis. Alfalfa, for instance, may be sown upon a soil needing lime, after the soil has lain fallow during the summer. The young plants appear to thrive in the fall, when the temperature is fairly low and the conserved soil moisture is heavily impregnated with CO_2, and therefore correspondingly high in carbonates from the hydrolyzed silicates. At this stage of their growth they are receiving lime sufficient for their needs, though they may later die from the lack of lime. There is of course the factor of a store of nitrates to feed upon—nitrates formed by the action of carbonated soil water upon the nitric acid, resulting from soil nitrification processes. Though stimulating, this nitrate offering will not replace needed lime, and as the plants grow and require more lime, the meager supply in the soil solution is consumed. If the soil solution's alkalinity were greater—if it were sufficient to offer requisite plant-food requirements of lime and also to afford an acceptable medium for nodule bacteria—the plants would continue to thrive, and themselves solve the question of nitrogen supply.

PROPOSED METHOD[1]

PREPARATION OF $CaCO_3$ STOCK SOLUTION

Pass purified CO_2 into one or more 4-liter cylinders containing distilled water and about 20 grams of "fluffy" C. P. precipitated $CaCO_3$ for 4 hours. Permit the CO_2 to enter with sufficient rapidity to keep considerable of the carbonate in suspension. At the same time prepare carbonated distilled water to the amount of about one-tenth that of the carbonate solution. Filter the carbonate solution through large gravity filters into the carbonated water. A large stock of 16 liters may be made and kept indefinitely without determinable change by use of the pressure-syphon bottle shown in Fig. 1. Upon withdrawal of each aliquot, pressure is maintained by blowing through the tube *A*. The $CaCO_3$ value of the solution is determined by first boiling and then liberating the CO_2 of the precipitated carbonate. *The value of the $CaCO_3$ solution should not be determined by direct titration, if the liquid absorption procedure be followed.*

1. This method was published in Jour. Ind. and Eng. Chem., Oct. 1915.

The HCl used in generator to liberate CO_2 for preparation of $CaCO_3$ solution should not exceed 1-1 in strength. To insure complete removal of hydrochloric acid from the rapid flow of gas, it is necessary to force the gas through the several columns of sodium carbonate solution when making large stock solutions of carbonate. A "Kipp" generator may be fitted with a 2-hole rubber stopper, a stand tube being inserted in one hole and in the other a stopcock-controlled tube for blowing to obtain pressure. A simple and more useful form of apparatus is that of Fig. 2.

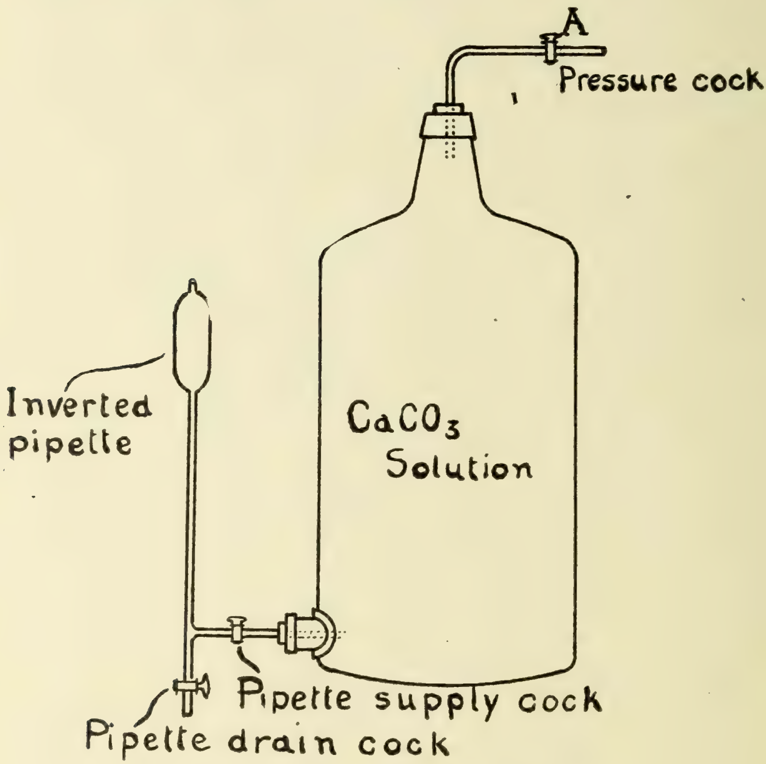

FIG. 1—PRESSURE CONTAINER FOR $CaCO_3$ SOLUTION

PROCEDURE FOR THE DETERMINATION OF THE IMMEDIATE LIME REQUIREMENT OF SOILS

For the average soil, take 10-gram charges of soil and 150 cc of $CaCO_3$ solution. This volume usually represents about .1500 gram of $CaCO_3$. For very heavy clays, or peaty or swamp soils, reduce the charge to 5 grams. Evaporate to a paste in 150-cc porcelain evaporating dishes. Transfer paste to a 300-cc Erlenmeyer flask, by means of CO_2-free distilled water, delivered by gravity from reservoir. (Such water may be easily

obtained in considerable quantities by slowly syphoning off boiling water, the volume of which is maintained by a gravity constant-level supply). Do not have volume of transferring water to exceed 60 to 70 cc. In unusual cases of adhesion of soil to dish, scour with a little $CaCO_3$-free sand. The tendency of the carbonate is sometimes to precipitate in a ring marked by the initial level of aliquot. Determine CO_2 by agitation and aspiration for 30 minutes, at room temperature, with 4 inches vacuum, using 5 cc concentrated H_3PO_4 to effect liberation of gas. Description of apparatus and detailed directions for manipulation of this determination were given in Tennessee Station Bulletin 100 and in the March (1915) number of the Journal of Industrial and Engineering Chemistry. Hydrochloric acid may be used insead of H_3PO_4, if proper precautions be taken for collection of volatile acid. The gravimetric method of absorption is decidedly preferable unless the analyst is thoroughly conversant with the technic of the liquid absorption and double titration procedure. Although absolute theoretical recovery of CO_2 in large amounts cannot be secured by the volumetric absorption, at room temperature, the factor is apparently uniform. However, the differential CO_2 values in the small charges used in the method may be accurately determined at ordinary temperatures if proper precautions be observed. (See Lincoln and Walton, El. Quant. Chem., p. 64).

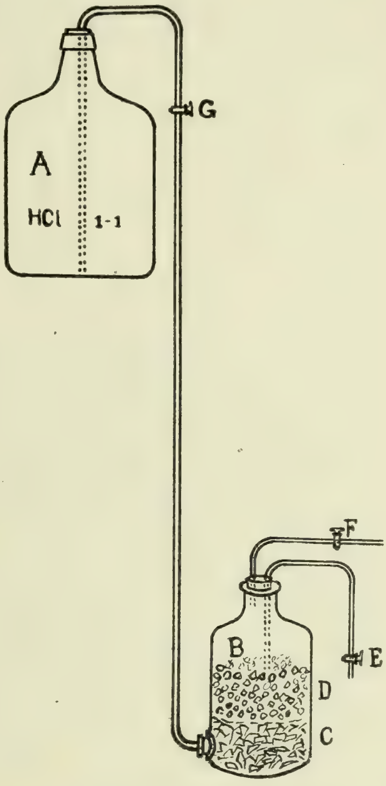

FIG. 2—CO_2 GENERATOR

a—16-Liter Acid Reservoir
b—4-Liter Generator
c—Broken Pottery
d—Marble-Sized Limestone Lumps
e—Geisler Cock Outlet for Spent Acid
f—Outlet for CO_2 to Purifiers
g—Safety Cock

In this laboratory we have secured very satisfactory results, even on large amounts of CO_2, by the procedure of precipitating the alkali carbonate formed in the absorbent solution with a constant maximum amount of neutral $BaCl_2$, and making to 500-cc volume with CO_2-free distilled water. An aliquot of 250 cc of the clear supernatant caustic liquid or the entire volume is then titrated directly with standard acid, using phenolphthalein as an indicator. From the

determined strength of the absorbent is then deducted the blank obtained in the same manner upon the original solution.*

Ten cc of approximately half normal NaOH or KOH, diluted to 50 cc with CO_2-free water, is sufficient to absorb the liberated CO_2. If the double titration procedure be followed, the number of cc of N/20 acid used in the methyl orange titration of the blank, minus that of the determined residual, will give, in terms of N/20 acid, the $CaCO_3$ decomposed by the soil. This number, multiplied by .005 gram and divided by the charge and multiplied by 100, will give the per cent of lime requirement in terms of carbonate of lime. If the barium chloride precipitation procedure be followed the difference between cc of titration of one-half of original absorbent solution after its treatment with $BaCl_2$ and that of 250-cc aliquot after absorbing CO_2 multiplied by the $CaCO_3$ value of titration-acid and divided by charge will give $CaCO_3$ requirement.

The small and nearly constant atmosphere blank of the apparatus is included in that of the added $CaCO_3$ and absorbent solution. This eliminates the necessity of rinsing the apparatus before each determination in order to remove any acid residual from the preceding determinations. This, together with the elimination of necessity for sweeping the apparatus free of atmospheric CO_2 prior to each analysis, greatly facilitates speed when making a large number of determinations. In very accurate work the slight action of the acid upon the soil organic matter in the cold should be recorded. The blank would then be run simultaneously upon the aggregate of a charge of the original soil equivalent to that used in the evaporation, the boiled $CaCO_3$ solution, the apparatus atmosphere, and the absorbent solution, if the volumetric absorbent method were used.

If the apparatus above specified for determination of residual carbonates at room temperature be not available, residual carbonates may be determined by bringing the soil and acid to boiling and continuing the boiling for *one minute,* with passage of purified air during boiling and for 30 minutes subsequently. A blank should then be run upon the acid soil in the same manner and correction made therefor. The boiling necessitates great care in order to prevent moisture being carried through the sulphuric acid into the soda-lime tubes. Camp absorption towers will be found to be very efficient in the drying of the evolved gas.

It is emphasized that the method here given is the result of an attempt to ascertain the conditions effecting the maximum laboratory decomposition of $CaCO_3$ by soils, and that its relationship to the question of crop response is a problem separate and distinct.

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* For larger amounts of CO_2 as in the determination of $CaCO_3$ in highly calcareous soils this procedure is decidedly superior to that of double titration.

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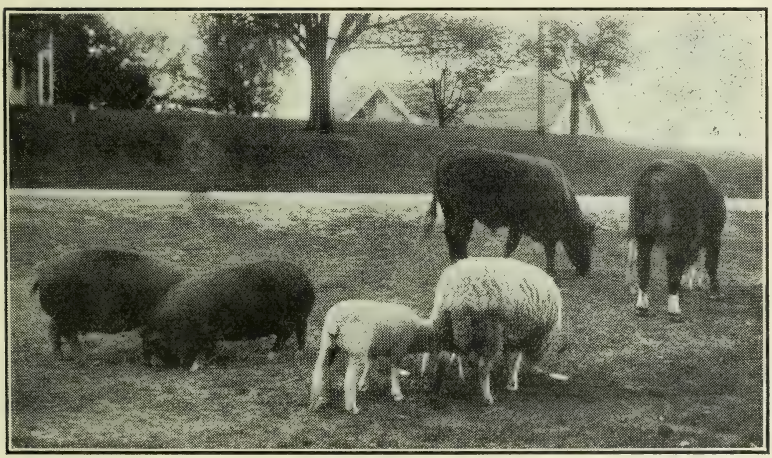
HOW TO FEED LIVE STOCK SUCCESSFULLY

BY

C. A. WILLSON



Live Stock Make Farm and Farmer Richer

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KNOXVILLE, TENNESSEE

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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

HOW TO FEED LIVE STOCK SUCCESSFULLY

By
C. A. Willson

It is not possible to lay down any set of rules by which one may become a successful feeder, for the successful feeding of farm animals is like any other business, in that the personal factor is the thing of greatest importance. There is no statement that is more true with regard to feeding than that it is "the eye of the master that fattens the cattle." The personal factor is too often disregarded in the feeding of farm animals. Good feeders are like poets, in that they are "more often born than made." More depends upon the man who does the feeding than upon the feeds used and the directions for feeding them. It not infequently happens that men who know nothing about feeding standards, balanced rations, or the composition of feeding stuffs make more successful feeders than do men who have learned all the facts about feeds and feeding standards.

TRAITS OF A SUCCESSFUL FEEDER

It is pertinent to inquire, then, who are, or who may become successful feeders of live stock. The feeding of live stock is more of an art than a science. To know all the rules and the science of feeding is of valuable assistance to the man who wishes to learn how to feed farm animals, but, like painting, one must learn the art through practice. The man who will be the successful feeder is the man who loves the work and the animals that he works with. There must be a bond of sympathy between the feeder and the animals that he cares for. No man can be a successful feeder whose animals are in constant fear of him or who is not liberal with his animals and does not love to see them eat. The man who can feed the most animals in the shortest length of time is not the most desirable feeder, but rather the man who has the greatest personal knowledge of all the animals at each feeding time. It is more important that a man observe each animal at each feeding time than that he perform the operation with dispatch. The man who feeds and runs away may not feed some of the animals the next day. Know the health and appetite of every animal. Be gentle. It is said that

"the breath of some men is poisonous to their animals"; animals do not do well in their presence. There can be no success in feeding where the animals fed fear their master.

Some men excuse themselves for the condition of their animals by saying that they were unfortunate in the selection of the breed to begin with. There is an altogether too prevalent idea that there are differences among breeds as to the economy and rate of gains. There are warm advocates for all the breeds, and which one of the breeds will make the most economical gains depends upon the person who is doing the talking. As a matter of fact, there is little if any difference between breeds in the economy of gains, from point of view of feeds consumed per pound gain, if the animals considered are of like condition and stage of maturity. No one has proved that any one breed will put on gains with less feed than will any other. For example, many feeding experiments have been conducted at various experiment stations with the purpose of determining which of the breeds of hogs will produce the most economical gains. There seems to be no unanimity among the various trials that have been made, and the general conclusion has been that there is a greater difference among the animals of each of the breeds than there is among the breeds. A Jersey steer will make as economical gains from the standpoint of the amount of feed per pound of gain as an Angus steer. This does not mean, however, that one should use the Jersey for the production of beef, for no greater mistake can be made. While the feed consumed per pound gain may be practically the same, the price received for the pound of gain will be much less in the case of the Jersey. The Jersey will not have thick flesh along the back, but will store fat as caul and kidney fat, which sells at as low price as tallow. There will not be less than 2½ cents a pound difference in favor of the Angus, which means that a 1000-pound Angus steer would sell for $25.00 more than the Jersey steer. The same difference in values exists between scrubs and high grades.

One cannot afford to grow and finish for the market other than the highest grades.

The reason follows.

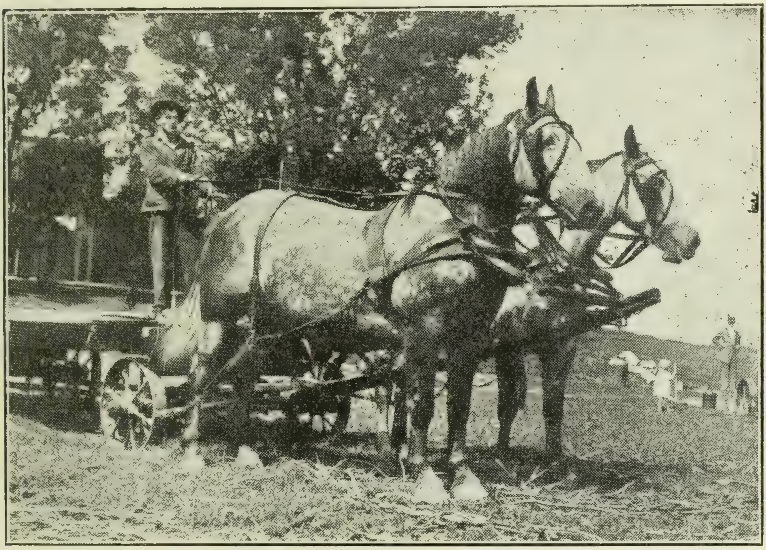
FEED ANIMALS OF THE RIGHT TYPE

The economic difference, then, between animals for successful feeding purposes is rather one of type than of breed. The type that will make the best use of feeds for the production of meat is the type that will put on the most meat in the regions of the most valuable cuts. The Jersey heifer may develop into the best type for the production of milk and butter, but would not be at all suited for the production of beef, owing to the small amount of porterhouse and prime-of-rib that she would make. She can digest food equally as well as the Angus heifer, but when not producing milk will put the fat resulting from digested food into other regions than those of the valuable cuts.

PRINCIPLES AND PRACTICE OF ANIMAL FEEDING

There are several principles that may be considered in the feeding of farm animals:

1.—**Always have a variety of feeding stuffs in the ration.** This is one of the fundamental principles in feeding, for if the feeder will but observe this one thing alone, being careful to keep within the limitations of the various feeding stuffs, he cannot help feeding somewhere near a balanced ration. A variety of feeding stuffs always gives better results than any one feed fed alone. For example, corn and wheat have about the same nutritive ratio, and when fed alone make an equally unbalanced ration, which will not be corrected in any way



Work Horses Will Do Well if Their Feed Is Adapted to the Amount of Work They Have to Do

through the combination of the two feeds; yet the combination may give much better results than either fed alone. If we define the limitation of soy beans, cowpeas, cottonseed meal, linseed meal, and gluten meal as 4 pounds per head per day for cattle, and as 1 pound per head per day for hogs, then we can hardly make a mistake in combining them with other grains produced on the farm for cattle and hogs. The greater the number of feeds incorporated into the ration the better will be the results.

2.—**Do not make sudden changes in the rations.** The beef steer may easily consume 16 pounds of grain per day if brought up to a full feed gradually, but if given that amount of grain before becoming

accustomed to large quantities it would suffer disastrous results. If the horse is fed on Sunday and on rainy days the same amount of feed as when performing heavy labor there has been made, in effect, a sudden increase in the ration, with, oftentimes, the result that the horse is sick during the forepart of the week and for the days following a rainy spell. If growing shotes are kept in a small pen during all of the winter months and then suddenly obtain access to a field of green wheat in the spring, they gorge themselves with a feed that would ordinarily be the very best for them but in this case does them a great deal of harm because they have not been accustomed to it. Salt is sometimes kept from the hogs until they have such a craving for it that they cannot resist the temptation to take more than they need, with the result that the salt poisons them. Salt is needed by hogs in the daily ration equally as much as by other animals, yet if a sudden increase in the amount of salt is given it may result disastrously. Eggs are very rich in the elements of salt, and if salt is kept from laying hens for a long period of time they may consume more of it than would be good for them, if they gain sudden access to it or a sudden increase in the amount of it is given them in the ration. All changes in feed rations should be made gradually.

If one has two kinds of roughage feed on hand, and neither one alone will last the cattle through the winter, but the two together will, it is usually better practice so to combine them in the daily feed that each last the winter through. Variety will be given the ration in that way, and much better results will be obtained than if one of the feeds is used for part of the winter and the other for the remainder. The same principle will apply to the feeding of grains. It is not good practice to feed one kind of grain one week and another kind the next week.

3.—**Do not feed animals that are extremely tired until they have time to become somewhat rested**, because much of the blood has been diverted away from the digestive tract. Food given to animals under such conditions often causes colic. Wait for at least an hour, until the animal can become rested somewhat, before giving the regular feed.

4.—**Water horses before giving them the grain ration**, because of the small capacity of their stomachs. The stomach of the horse holds only 17 to 19 quarts; hence water given immediately after the grain ration is very apt to wash a portion of the contents of the stomach out before the stomach digestion has been completed.

5.—**Do not disturb or unnecessarily exercise** dairy animals or animals on full feed. It requires from 30 to 40 per cent more feed to maintain an animal while standing on its feet than while lying down. A good feeder will not disturb his animals more than he can help, and will not set the dog on them, for wasted energy means wasted feed. Large feeders of lambs in the North say that they would rather give a visitor a five dollar bill than to show him through their feeding plant, because lambs quickly notice strangers, and where hundreds of

lambs rise to their feet more than five dollars worth of feed will be wasted. Holland dairymen milk their cows in the field instead of driving them to the farmyards. They get more milk through conserving the energies of their cows. Quietness and gentleness should be the rule in the feeding and handling of all farm animals.

6.—**Convert all cheap feed on the farm into some animal product.** Thousands of dollars worth of feed on Tennessee farms goes to waste every year. It has been estimated that more than $14,000,000 worth of corn stover goes to waste every year in this State. Every ton of straw, every ton of corn stover, every ton of cheap hay produced on Tennessee farms should pass through live stock, or should be used for bedding. Live stock farmers make more money than other farmers because they receive added returns through the use of low-grade feeds that otherwise would be wasted. Every ton of oat straw is worth $10, every ton of barley straw is worth $9, every ton of wheat straw is worth $6, and every ton of well-cured corn stover is worth from $8 to $10, for feeding purposes. Every foot of waste land on the farm should be grazed. Waste lands that are grazed grow more grass than lands that are not grazed, and when pastured are made to bring in additional returns to the farm.

7.—**Do not underfeed farm animals.** All feed is wasted when given to an immature animal that does not make some growth. The pig that goes to sleep at night without having made some gain during the day has wasted the feed that was given it. Withholding feed in order to save it is wasting it. Farm animals should always be given all the feed that they will consume with a relish. It is only the character of the feed that should be changed. Cattle that are being wintered over may be given cheaper feed than grain, such as well-cured corn stover, straws, etc., but they should be given all that they will consume with a relish. Hogs may be given cheaper rations than full feeds of grain, such as green forage crops, but they should be given all that they will consume by being provided with luxuriant forage crops. Horses may be wintered on cheaper feeds than full rations of hay. They should, however, be provided with all the clean, bright, cheap straw and stovers that they care to eat. It does not pay to withhold feed from farm animals.

8.—**Do not overfeed farm animals.** Occasionally there are feeders who overfeed, although it does not often occur. The best rule is to feed only as much as the animals will clean up thoroughly before the next feed. Palatability is one of the principal factors in the feeding of farm animals. There is a greater secretion of digestive juices when a food is palatable to the animal, and hence a more thorough digestion. If animals on full feed do not clean up their feed from one feed to the next the feed boxes should be cleaned out, and fresh clean feed put in, in a little lessened amounts.

9.—**Do not give animals moldy feed.** Much of the food value has been lost through the growth of the molds and fungi, and further than that it is very dangerous to live stock, especially horses. If grains become moldy they may be with some degree of safety fed to hogs if they are cooked and then mixed in equal proportions with the other grains.

10.—**Do not incur too much expense in feeding.** The feed must pay for the expense before it can begin to give returns on the investment. Multiplicity of operations in the feeding of farm animals means added expense. Cattle should not be fed singly in stalls where they can be fed in groups. Feeds should not be cut, shredded, or ground when they would give practically as good results without such preparation. Live stock should not be fed three times per day when twice will do just as well. Corn broken from the stalk with the husk on and later ground with cob, husk, and all will give as good results for cattle as corn that has had the extra operation and cost added to it of removing the husk. Corn broken in pieces with a hatchet in the feed bunks of the finishing cattle will be more profitable where hogs follow the cattle than corn that has had the extra expense added to it of grinding. Hogs, except when on full feed during the last three weeks of the finishing period, make more profitable gains when fed ear corn than when fed ground corn. It is a common saying that "a sheep that cannot grind its own feed is not worth having." It is doubtful whether it will pay to shred corn stover unless the corn can be husked more cheaply or the manure handled more economically. It will not pay to grind good, bright alfalfa hay, soy bean hay, or cowpea hay for cattle, horses or sheep. There is a tendency to add too much to the cost of feeding stuffs through extra manipulations of the feed.

11.—**Do not feed condimental stock food to healthy animals.** If any of the animals are sick consult a veterinarian. Average results with condimental stock foods show that where there are added gains with stock foods, the extra expense incurred more than offsets the added gains.

12.—**Mix feed on the farm whenever possible.** Commercial mixed feeds are often mixed for the purpose of obtaining a high price for such low-valued feeds as corn bran, rice hulls, rice straw, low-grade alfalfa, cottonseed hulls, buckwheat hulls, oat hulls, and screenings. The farmer can mix these with such feeds as corn, low-grade wheat, feeding molasses, and cottonseed meal and secure a mixed feed at a low cost.

13.—**The solid manure is a perfect indicator of the health of the animal.** When the manure passing from the animal is hard it indicates that either the animal is feverish, or the feed is too constipating. If the manure is too soft it indicates the food is too laxative, or too stimulating to the bowels, or that the animal has been overfed. Any

of these conditions is the first warning the feeder will have that the animal is off tone. The wise feeder will heed the warning, seek the cause, and correct it. At the very first indication of looseness of the bowels of animals that are on full feed, lighten up on the feed. Do not wait until the animals refuse entirely to eat. If the manure is too hard give a good dose of raw linseed oil or of epsom salts. If the trouble is due to the ration, correct the ration.

14.—**Feed farm animals where the manure may be recovered.** Wherever practical, feed on land that may later be plowed. The greater part of the manure of pigs fed in pig sties or manure thrown in open, wet, muddy barnyards is lost. It is possible to save of the fertility of the feeds fed, 22.5 cents worth for each bushel of wheat; 11.3 cents for each bushel of oats; 19.9 cents for each bushel of corn; 18.7 cents for each bushel of barley; $8.19 for each ton of clover hay; $4.49 for each ton of meadow hay; and $26.57 for each ton of cottonseed meal. Plan to save every particle of the manure. The fertilizing elements in it are more valuable than the same elements contained in commercial fertilizer. You would not leave a ton of fertilizer standing out in the rain.

WHAT CONSTITUTES A FULL FEED

Failure to get the best returns sometimes results from a lack of knowledge of the general limitations with regard to the amounts of feed that should be given under various conditions.

Horses.—A general rule as to amounts of grain for horses is, to feed ½ pound of grain per hundredweight per day for horses doing moderate work; 1 pound per hundredweight per day for horses doing medium work; and 1½ pounds per hundredweight per day for horses doing heavy work.

Beef Cattle.—Ordinarily a full feed of grain for beef cattle, where silage is fed, should be from 12 to 14 pounds per head per day at the end of the finishing period. Best results are obtained with cottonseed meal when not more than from 6 to 7 pounds are fed per head per day at the end of the finishing period. But little grain should be given during the first one-third of the finishing period.

Dairy Cows.—The rule for feeding grain to dairy cows is to feed during the winter 1 pound of grain for every 3 to 3½ pounds of milk produced. For example if the cow gives 30 pounds of milk per day she should be fed from 8½ to 10 pounds of grain. If grain is fed to cows while on pasture it should be fed in one-half the amounts recommended for winter feeding. Every added pound of grain that will produce three pounds of milk is profitable.

Hogs.—A full feed for hogs during the finishing period is from 3 to 3½ per cent of the live weight per day. A hog weighing 200 pounds

will consume, then, from 6 to 7 pounds of grain per day. Hogs on pasture, before the latter part of the finishing period is reached, should not be fed larger amounts than 2¾ per cent of their live weight per day when the pasture is good. If given a full feed they will not make the best use of the cheaper forage crops, and the gains produced will be more expensive.

The greater the amount of milk fed per day to hogs, the less value per hundredweight may one obtain for it. One should not feed to hogs more than from 3 to 4 pounds of milk for every pound of grain fed. Even less than that proportion will give a higher value per hundredweight for the milk.

Sheep.—One pound of grain per head per day is liberal feeding for sheep. During the latter part of the finishing period sheep sometimes consume from 2 to 3 pounds per head per day.

Calves.—A good rule for the feeding of milk to calves is, to feed daily 10 pounds of milk for the first 100 pounds live weight, 5 pounds for the second 100 pounds live weight, and 2½ pounds for the third 100 pounds live weight. A 200-pound calf, for example, should be fed daily 15 pounds of milk, and a 300-pound calf should be fed 17½ pounds. A quart of milk weighs approximately two pounds.

COMPARATIVE VALUES OF FEEDS

In order to compare feeds, one must use such terms as "protein", "carbohydrates", and "fat". These are materials occurring in all feed stuffs, but in different amounts. "Protein" may be defined as the "muscle-forming" compounds of feeds. One of the common proteins is the white of egg, sometimes called "egg albumen". "Carbohydrates" and "fat" may be defined as the "fat-forming" compounds of feeds. These also are used for the production of heat and energy. Starch and sugar are the most common carbohydrates. Linseed oil is a fat obtained directly from flaxseed; soy bean oil from soy beans; and rapeseed oil from rapeseed. The amounts of these compounds in feeds that animals can make use of, or digest, is spoken of as "digestible protein", "digestible carbohydrates", and "digestible fat". By the term "ration" is meant the total amount of feed an animal will eat in a day, and not the amount that is given for any particular meal. It is a collective term meaning "all the feed given".

No hard and fast rules can be laid down for determining the values of feed stuffs, or their relative values, owing to the large number of factors that enter into calculations. A few general rules may be given that will be of some assistance in approximating such values. A feed may also be compared with other feeds.

Milk.—There are two rules for approximating the value of skim-milk for fattening hogs:

1. To find the value of 100 pounds of skimmilk multiply the market price of live hogs in cents per pound by 6 when the skimmilk is fed in combination with corn, barley, or wheat.

2. When fed along with corn, 100 pounds of skimmilk is worth one-half the price of corn per bushel. These values are in terms of corn saved.

Buttermilk and skimmilk have the same value for hog-feeding purposes where no water has been added to the milk.

Whey.—For pig-feeding purposes whey is worth about one-half as much as skimmilk.

Corn.—When corn is properly balanced with other feeds 1 bushel will produce 12 pounds of gain with hogs; when not balanced with other feeds, the rule is that 1 bushel will produce 10 pounds of gain.

Corn, wheat, and barley, when properly balanced with other feeds, are worth practically the same per pound for feeding purposes.

Kafir corn, sorghum, etc.—These feeds are practically of the same composition as corn, but not quite so palatable. Feeding trials show that it takes from 6 to 7 pounds of these to equal 5 pounds of corn.

Oats.—This feed is generally overrated. One hundred pounds of oats contains but 2.2 pounds more of digestible protein, or "muscle-former" than 100 pounds of corn, and contains 15.6 pounds less of carbohydrates, or "fat-former". One quart of whole corn contains twice as much digestible material as one quart of whole oats. On the pound basis oats are really worth a little less than shelled corn.

Wheat bran.—Only a little more than one-half of bran is digestible, or can be used by the animal. It has only 4.7 pounds more digestible protein, or "muscle former", in 100 pounds than corn and has 26.9 pounds less of carbohydrates, or "fat-former". It is low in lime, which is the principal ash of bones. Its chief value in the ration is as a diluent. Ground alfalfa hay, soy bean hay, or cowpea hay is equally valuable for the same purpose. When cottonseed meal sells at from $30.00 to $35.00 per ton, bran is not worth, as a source of protein, or "muscle-former", more than $20.00 to $23.00 per ton.

Corn bran is not palatable and is worth about four-fifths as much as wheat bran for feeding purposes.

Wheat shorts.—This wheat by-product contains a little more protein and a little more carbohydrates than wheat bran. It is worth from $1.00 to $2.00 more per ton than wheat bran.

Cottonseed meal.—There is three times as much digestible protein in cottonseed meal, and as much digestible carbohydrates and fat combined as in bran. As a food to balance a corn ration, it is worth twice as

much as wheat bran. One pound of cottonseed meal will balance as much corn as three pounds of bran.

Sometimes the analysis of the cottonseed meal offered for sale is given in terms of nitrogen, or of ammonia, on the tag, or is quoted by letter in those terms, when the probable purchaser desires most of all to know the protein content. One may readily transform these factors into terms of protein by using the following factors:

When the analysis is given in terms of nitrogen, multiply by 6.25. For example, if the analysis is given as 7 per cent nitrogen, then the pounds of protein in 100 pounds of the cottonseed meal would be 6.25x7, which equals 43.75; and this would mean that it was a very choice grade of meal.

When the analysis is given in terms of ammonia, multiply by 5.15. For example, if the analysis is given as 8 per cent ammonia, the pounds of protein in 100 pounds of the cottonseed meal would be 5.15x8, which equals 41.20; and this would mean that it is a good grade of meal. If the analysis is given as 6.85 per cent ammonia it would be a low-grade meal, for the protein contained would be 35 pounds in every 100 pounds of the cottonseed meal.

Linseed meal.—This by-product has a little less protein than cottonseed meal, but on account of its soothing effects on the bowels when fed with other feeds it is considered to be equal to cottonseed meal.

Soy beans.—There is no other feed that can be grown on the farm that is the equal of soy bean grain in protein content. It has 31 pounds of digestible protein in every 100 pounds, and is very high in fat content. It may be used in the ration, pound for pound, in place of cottonseed meal or linseed meal. It should never be fed in large quantities in the ration on account of its high protein and fat content.

Soy bean cake, and soy bean meal made from cake.—Mills for the extraction of oil from soy beans are being established throughout the South and soy bean cake will soon be a common feed stuff on the market. It has a slightly greater feeding value for dairy cows than cottonseed meal. In analysis it is slightly higher in protein than cottonseed meal, and has practically the same amounts of carbohydrates and fat.

Alfalfa hay, soy bean hay, and cowpea hay.—These hays, when well cured, are practically equal in feeding value, and are worth about the same as bran ton for ton. They are rich in lime, which is the principal ash of bones and this ash is largely lacking in bran. When fed very liberally they are sometimes too laxative. The remedy in such cases is to lessen the amount in the ration by substituting for awhile in the ration a little timothy or other grass hay.

Tankage.—This is a packing-house by-product that is especially adapted for balancing the corn ration for hogs. It is rich in protein,

or "muscle-former", and ash material and is especially palatable to hogs. It is worth 1½ times as much per ton as linseed meal or cottonseed meal and 2 to 3 times as much as bran.

Potatoes, apples, root crops, pumpkins, etc.—Succulent, watery feeds like these usually require from 3 to 4 pounds to equal 1 pound of corn. Such feeds should never make up more than one-half the ration. When not supplemented with grain a ration made up entirely of such feeds is too bulky to make gains or produce milk and is no more than a maintenance ration.

Corn silage.—The average cost of producing silage is about $3.00 per ton, and hence it is usually figured in at that amount when cost factors are considered in arriving at conclusions in experimental results. Experiments have shown that from $6.00 to $9.00 may be obtained for every ton of silage fed to finishing steers. Even more than that may be obtained for silage fed to high-producing dairy animals. In experiments at the Tennessee Experiment Station a value of $7.65 per ton was obtained for silage fed to finishing steers that received a medium amount of cottonseed meal for the grain ration. Soy beans, cowpeas, or alfalfa should never be made into silage, when they can be made into hay, for nothing will be added to their palatability or feeding value.

Straws.—Every ton of well-cured and well-preserved straw on Tennessee farms has a feeding value of $6.00 to $9.00 per ton. The relative values of the various straws rank as follows: Oat straw, barley straw, wheat straw, and rye straw.

Corn stover.—Good corn stover, well cured in the shock, has a feeding value equal to cottonseed hulls. Some experiments show that it is decidedly superior to cottonseed hulls. One ton of well-cured corn stover is worth three-fourths of a ton of timothy for horses and cattle. The stover is best if put into the shock and tied tight, close to the top. When the ear is well glazed, and after husking, it should be stored in stacks. Corn stalks left standing in the field subject to the effects of the weather very soon lose practically all their feeding value.

Cottonseed hulls.—The digestible content of cottonseed hulls, or the amount the animal can make use of, is less than that of oat straw, and they, therefore, are not so valuable. They also are of less value for feed than well-cured corn stover.

BALANCED AND STANDARD RATIONS

The term "balanced ration" is used so carelessly that many persons understand it to mean a sort of standard ration for each class of animals that will do for all ages and conditions of animals in that class. A ration is properly "balanced" for any animal when it supplies all the food elements in the proper proportion for that particular animal.

One can readily see, then, that as the demands of the animal body change, so must the ration change.

The young, rapidly growing animal needs a much larger proportion of protein, or "muscle-former", in the ration than that same animal after it becomes mature and protein is less needed for the building of muscle.

The dairy cow that is producing large amounts of milk, which is rich in protein material, needs much more protein in the ration than the cow that is being fattened. Laying hens must be supplied protein in the ration for the eggs, which are rich in that material.

The brood sow that is secreting large amounts of protein, lime, and phosphorous in the milk to be used by the rapidly growing pigs must be supplied those elements in liberal quantities, or they will draw from her own muscles and bones in order to keep her milk to a constant quality, with the result that the sow soon breaks down. If lime is not supplied in the ration of the laying hen she must necessarily produce shells without lime, which will be soft-shelled eggs. If the growing pig is fed only corn, which is very low in ash and protein, it will fatten, but will grow but slightly, for there is little material present for the making of bones and muscle. Salt is another material that is necessary to the ration. It tends to correct digestive disorders, for it contains elements that are necessary constituents of some of the digestive juices. It is just as necessary for poultry and hogs as for other classes of animals.

In order to make plain the discussion relating to the balancing of rations, the following explanations of terms are given:

Dry matter is the total material in the ration or feed that would be left if the feed were oven-dried so as to expel all the water. All hay and grains contain some water. The amount varies according to the degree of thoroughness with which the feed is air-dried. Usually hays and grains that are well cured contain from 9 to 12 pounds of water in every 100 pounds. Silage contains from 70 to 80 pounds of water in every 100 pounds. Hay and grains, then, contain from 80 to 91 pounds of "dry matter" and silage from 20 to 30 pounds of "dry matter" in every 100 pounds.

Digestible protein in the ration is the protein available to animals that exists in varying proportions in the various feed stuffs; it is present in all plants, and is the material that is necessary to the animals for the building up of muscle and bone tissue. If it is not present in sufficient quantities in the ration or feed, of the young, growing animal, then that animal may not be able to make a normal growth. The white of egg is largely protein, or "muscle-former". The casein of cheese is protein. Soy beans, cowpeas, alfalfa hay, cottonseed meal and clover hay are examples of feeds that are rich in protein. The milch cow must receive a sufficient amount of it before she will reach her maximum supply of milk, because milk is rich in protein;

the growing animal must have it to attain its maximum rate of growth; and the hardworking animal must have it to repair the muscular tissue that is worn out in the production of work.

Digestible carbohydrates is such material as starch, sugar, and digestible crude fiber tissue that the animal can make use of. It is stored in the animal body in the liver, and is also transformed into fat. It is the material used in the animal body for the production of work. As stored carbohydrates in the liver or as carbohydrates that have been transformed into fat, it represents stored energy that may be used at any time for the production of work. Some of the feeds that are rich in carbohydrates, or "fat-formers", are corn, wheat, barley, rye, sorghum seed, and potatoes.

Digestible fat is, as the name implies, the oils found in feeds that the animal can make use of. It serves exactly the same function in the animal body as carbohydrates. It is also a "fat-former" or "energy-producer". One pound of fat in feeds is as valuable to the animal for the production of work as 2¼ pounds of carbohydrates, for it contains 2¼ times as much stored energy. A few feeds that are rich in oils, or fats, are soy beans, peanuts, acorns, and nuts. The maximum amount of digestible fat that should be contained in any ration for 1000 pounds live weight is 1 pound. More than that might cause digestive disturbances.

Total digestible nutrients is the sum of the digestible protein, the digestible carbohydrates, and the digestible fat x 2¼.

Ash is the material that is left after burning. There are several elements found in the ash, the principal ones of which that are useful to the animal being calcium, or lime, and phosphorus. Over 80 per cent of the ash of bones is made up of these two elements. They, then, are very essential in the ration of the young, growing animal. Feeds that are rich in the elements calcium and phosphorus are all of the legume hays, such as soy bean hay, alfalfa hay, red clover hay, cowpea hay, and crimson clover hay. Bran is rich in ash, but its ash is low in calcium.

Nutritive ratio is the relation that exists between the digestible protein on the one hand and the digestible carbohydrates and digestible fat on the other, after the fat has been multiplied by 2¼. For example, the digestible nutrient content of corn is protein 7.5 pounds in 100, carbohydrates 67.8, and fat 4.6 pounds.

The nutritive ratio, then, is $\dfrac{67.8 + 2\frac{1}{4} \times 4.6}{7.5} = \dfrac{10.4}{1}$

or 1: 10.4; that is, the nutritive ratio of corn is 67.8 plus 2¼ times 4.6 divided by 7.5, which equals 10.4; or the ratio of the protein to the combined carbohydrates and fat is as 1 to 10.4. This relation between

the protein and the combined carbohydrates and fat has been found to be too wide for nearly all classes of animals, and therefore corn should practically always be combined with some other kind or kinds of feed, so as to add to the protein content and thus produce the best results. A ration is considered wide when the nutritive ratio is as 1 : 8 or greater; medium when the ration is as 1 : 5 to 7; and narrow when the ratio is as 1 : 4 or less.

Digestible nutrients—Protein, carbohydrates, fat, and ash are "nutrients". The amounts of these that the animal can digest are collectively called digestible nutrients.

HOW TO BALANCE A RATION

Scientists have determined just how much dry matter, ash, protein, carbohydrates, and fat will without waste, exactly meet the requirements of each kind of animals for each age and condition. The amounts required for any class and age of animals are called a "feeding standard" for that particular class and age. A ration ordinarily is said to be "balanced" when it exactly contains the food elements as given by the "feeding standard" for the particular class and age of animals to which it is to be fed. The "standard ration", for example, for 1000 pounds live weight of fattening pigs weighing 200 pounds each is—

Dry matter	Digestible crude protein	Total digestible nutrients	Nutritive ratio
Lbs.	Lbs.	Lbs.	1 :
25.5-28.1	3.0-3.4	22.77-25.0	6.5-7.3

This standard ration means that experimenters have found that 1000 pounds live weight of 200-pound hogs will need the amounts of the various materials as given above in order to make the best and the most economical gains.

If one knows the amount of dry matter in a day's ration, the amount of protein, and the total amount of digestible nutrients that an animal should have, and also the amounts of these in feed stuffs, it is easy enough to calculate how nearly any given day's ration supplies the proper amounts that the animal should have according to the standard for that particular animal. (Table II in the Appendix gives the amounts of digestible nutrients in the various American feed stuffs and Table III gives the standard rations for various classes and ages of farm animals). If the "total digestible nutrients" in the ration is high and the total amount of "digestible protein" is low, then some feed rich in protein should be substituted in the ration for some of the feed that is evidently high in carbohydrates and fat and low in protein. The amount that must be substituted in order to make the ration balance can only be determined by trial until the ration is made to balance according to the standard.

Suppose that we try making a balanced ration for a hog weighing 150 to 200 pounds on full feed that is being fattened for the market.

The standard ration for 1000 pounds of live weight of such hogs is—

Dry matter	Digestible crude protein	Total digestible nutrients	Nutritive ratio
Lbs.	Lbs.	Lbs.	1:
29.0-32.0	3.5-3.9	25.8-28.5	6.2-7.0

A 200-pound hog would require one-fifth of the above standard for 1000 pounds live weight, or the standard for a 200-pound hog would be—

Dry matter	Digestible crude protein	Total digestible nutrients	Nutritive ratio
Lbs.	Lbs.	Lbs.	1:
5.8-6.4	.70-.78	5.1-5.7	6.2-7.0

The dry-matter factor is useful as a guide to show approximately how much feed the animal will consume in a day's ration. The rules given on pages 57-8 will also be found useful in determining how much grain will be required in the ration for a day's feed. Corn has about 89.5 pounds dry matter in every 100 pounds. We may estimate, then, that a full feed of corn for a 150- to 200-pound hog would be from 6¼ to 7 pounds. As a matter of fact, corn is too often used as the exclusive feed for this weight of hogs. Suppose that we determine how near a straight corn ration would be to the standard requirements for this sized hog:

	Dry matter	Digestible crude protein	Total digestible nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	1:
6½ lbs. corn ----	5.8	.49	5.57	10.4

We note that the ration is entirely too low in the amount of protein that is required according to the standard. This is indicated in another way; namely, in the nutritive ratio, which is entirely too wide. The standard ration for a 150- to 200-pound hog is 1: 6.5. When the dry-matter factor is correct a wide nutritive ratio indicates either that the protein is too low or that the total digestible nutrient factor is too high on account of the digestible carbohydrates and digestible fat being too high. By trial we find that if we substitute in the above ration 1¼ pounds of soy beans for 1½ pounds of corn we shall have a ration that will balance according to the standard requirements, and which will therefore be according to the daily needs of the hog. The ration balanced is, then, as follows:

	Dry matter	Digestible crude protein	Total digestible nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	1 :
5 lbs. corn ______	4.4	.38	4.14	
1¼ lbs. soy beans	1.2	.38	1.07	
	5.6	.76	5.21	6.2

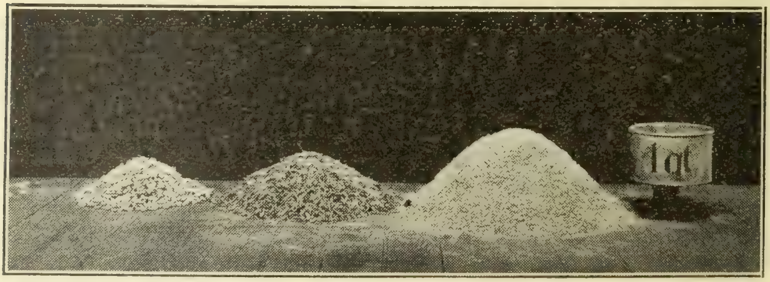
The following rations would prove equally as well balanced and equally as efficient for the same weight of hogs:

1. 4½ pounds corn and 2 pounds cowpeas.
2. 6 pounds corn and ½ pound tankage.
3. 4 pounds corn and 2½ pounds wheat shorts.
4. 2 pounds corn, 2 pounds barley, and 4 quarts skimmilk.
5. 2 pounds corn, 2 pounds barley, 2 pounds wheat and ¼ pound tankage.

The last ration is the best of all on account the larger number of feeds entering into it. In considering rations of equal balance, one may generally consider that ration will be most economical to use that can be purchased the cheapest. What feeds to use, then, will depend upon the price of the ration in each case after it is balanced.

FEEDING HORSES

The feeds that ordinarily are considered most adaptable for horses are oats, wheat bran, and timothy hay, although such feeds as clover hay, alfalfa hay, and corn are commonly used. The reason why oats and bran have gained such a good reputation for horses is that they have been the safest to feed. A quart of shelled corn contains twice as much food material as a quart of whole oats and five times as much as a quart of bran. Changing from either one or both oats and bran, to corn, measure for measure, always means a great change in the ration. Such sudden changes are oftentimes attended with bad results,



One Quart Shelled Corn — Two Quarts Whole Oats — Five Quarts Bran

Each Lot of Feed Here Shown Has Practically the Same Feeding Value as the Others

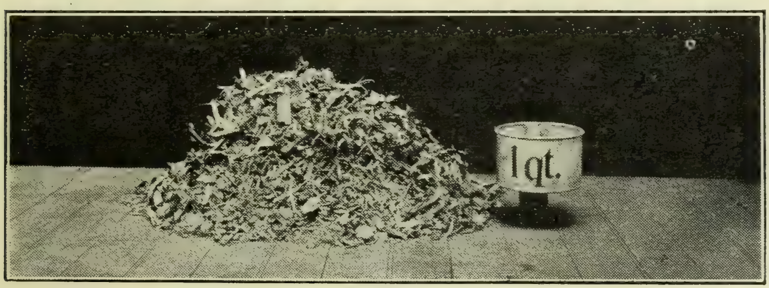
and hence we often hear it said that corn is "more heating" than oats, or oats and bran, or it is condemned because the horses get sick in making the change. The corn is not to blame, but rather the feeder, who did not know that corn is a very much more concentrated feed and that half a quart of corn would replace in the ration a quart of

One Quart of a Mixture of Six Parts Corn and One Part Cottonseed Meal. Three Quarts of a Mixture of Seven Parts Ground Oats and Two Parts Bran.

Either of These Amounts Will Be as Effective in Feeding the Horse as the Other

oats, and that one quart of corn would replace five quarts of bran. Corn is an especially valuable food for horses when fed intelligently.

Other feeds that may be used for horses are any of the straws that are bright and clean, bright, well-cured corn stover, silage, millet hay when it does not make up more than one-half the roughage ration, well-cured soy bean hay for not more than one-half the roughage



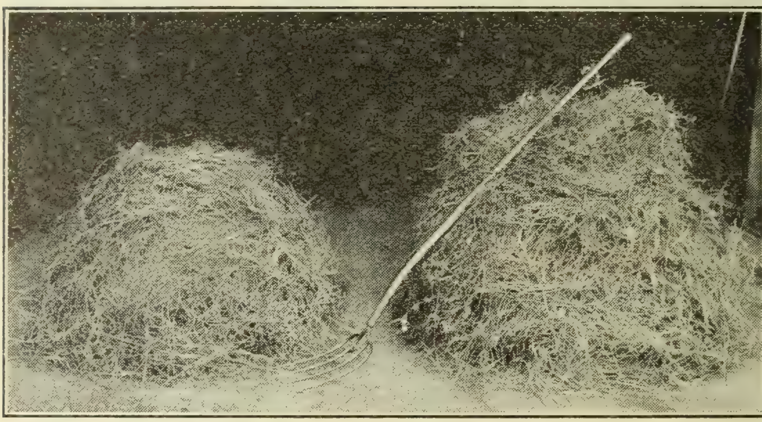
Six Pounds of a Grain Mixture Made Up of Six Parts Ground Corn and One Part Cottonseed Meal. This is Diluted with Five Pounds of Silage

Here Is a Single Meal for a Horse

ration, cowpea hay for not more than one-half the roughage ration, sorghum hay for not more than one-half the roughage ration, cottonseed meal with a limit of 2 pounds per head per day, and barley. A combination of several of these feeds would be much better than any two of them. Such feeds as bright

corn stover and bright, clean straws could well be used in the horse's ration to help cheapen it. Cottonseed meal within the limitations given, is one of the very best feeds for horses. One pound of cottonseed meal will replace in the ration from 2 to 3 pounds of wheat bran and 1 quart of cottonseed meal will replace in the ration from 8 to 10 quarts of bran. One quart of a mixture of ground feed consisting of 6 parts ground corn and 1 part cottonseed meal (parts by weight) would be equally as effective as 3 quarts of a mixture of ground feed consisting of 7 parts of ground oats and 2 parts of wheat bran.

Silage is an excellent feed for horses. Care should always be taken, however, that no moldy silage is fed. Ordinarily it should not



Fourteen Pounds Hay Twenty-two Pounds Hay

The Work Horse Should Be Fed the Smaller Amount Each Day He Is at Work. He Will Eat the Larger Amount on Sunday or on a Rainy Day if the Manger Is Kept Full. To Keep the Work Horse Well He Must Be Fed Less on Days He Does Not Work.

be fed in greater amounts than 5 pounds at a feeding. It may be fed at the same time as the grain ration, as a diluent for the grain ration. There is no better method of feeding the grain ration than to mix it thoroughly with about 5 pounds of silage at each feed.

Do not feed moldy, musty, and dusty feeds to horses, for this class of animals is very susceptible to the poisons in these feeds. Moldy silage and moldy hay should always be discarded.

Feeds that are heavy and concentrated in character, like corn and cottonseed meal, may be diluted with cut hay, silage, or cottonseed hulls.

The feeding of the work horse demands much consideration, for work is the ultimate use of the horse. The efficiency of the horse for the production of work depends in a large measure upon how he is fed and cared for. The amount of feed given should be according

to the amount of work done. (See page 57). If the work ceases for a day, on account of rainy weather or Sunday, the feed should be lessened for the time. Most of the severe digestive disturbances of horses occur during the first three days of the week following the heavy feeding of Sunday without the production of work, or for the two or three days following rainy weather. To give the horse the same ration when idle as when at heavy work amounts in effect to an increase in the ration and violates one of the principal rules of feeding. (See page 53). It is exceedingly harmful to a horse that has been putting in long hours at heavy labor during the week to stand at a manger all day Sunday or on a rainy day and consume hay throughout the entire day.

The ration for a horse that is at heavy labor should be richer in protein feed than for a horse that is doing light work, since the muscles are worn more rapidly and the worn tissue must be replaced with protein. Feeding standards say that the ration for the horse at heavy labor should have a nutritive ratio of 1: 7 or 8, while for horses that are idle it may be 1: 9 or 10. While carbohydrates, or "fat-formers", are the principal food elements needed for the production of work, protein is needed to repair wear. A machine cannot be used without some wear. For that reason clover hay when bright and clean is better for horses at heavy labor than timothy hay. If it is not bright and clean, use timothy hay. For rations for horses see page 104.

During the seasons of the year when the horse is not at heavy labor, the roughage part of the ration may be made up principally of bright, well-cured corn stover and clean, well-cured straws. Ten pounds per day of good corn silage added to such a ration would materially increase its efficiency.

The brood mare should be given work, up to the time of foaling, where there is a good, firm footing, in order that she will be certain to have sufficient exercise. The rest for the brood mare should come during the three to six weeks after foaling instead of before. The ration of the brood mare should have more protein in it than the ration of the work horse, for in addition to the repair of worn muscle tissue in the production of light work, she must have protein for the production of a foal whose body compounds are largely protein. For that purpose such feeds as bright clover hay, alfalfa hay, soy bean hay, and cowpea hay should be given the brood mare. They should be continued after foaling also, for they are well suited for the production of milk.

It is best that the brood mare be worked until nearly the hour for foaling. In order that the bowels may be in good, laxative condition, they should be cooled out through the use of bran mashes just before and immediately after foaling. The brood mare should be fed lightly of grain for four or five days after foaling. Bran mashes are the only feeds that need to be given during that time.

Always plan to be present at the time of foaling, for oftentimes

a little assistance to the mare at foaling, or so simple a thing as the removal of the thin membrane of the "foal blanket" from the foal's nose at the time of birth may be the means of saving what has been looked for with eagerness for nearly a year. The navel cord should be ligated with heavy white thread or catgut, to prevent bleeding from foal, and then severed. It is considered good practice to paint the navel immediately with tincture of iodine in order to prevent infection that will cause navel ill.

A very good grain mixture for the mare while suckling the foal would be—

Corn 2 parts.
Barley 2 parts.
Oats 2 parts.
Cottonseed meal 2 parts.
Bran 2 parts.

As soon as the foal will take grain, it should be fed, in a separate box from the mare, a grain mixture of equal parts of whole corn, barley, and oats. Keep bright, clean soy bean hay or clover hay before the colt. Do not allow it to follow the mare when she is put to work, after the four-weeks rest that will be given her. The colt is much better off if kept during the day in a dark stall, where the flies will not bother it and where it will not be worried with following the mother about. During the first few days that the mare is taken from the foal to work, it is best, where at all possible, to bring the mare to the barn during the middle of each half day and allow the foal to suckle. Where that cannot be done, the mare should be milked out enough to relieve the tension of the udder during the middle of each half day. If the mare is very warm when brought in from work she should be allowed to cool off before the colt is permitted to suckle.

Feed the colt well, for the mature weight of the horse is as much determined by the manner of feeding the colt during the first year as it is upon breeding. Horsemen have the rule that "the colt will reach more than one-half its mature weight during the first twelve months of its life." If a large weight is not reached during the first year a large mature weight will not be reached. Starving the colt during the first year will lower the final mature weight. Good, bright legume hays, such as clover, alfalfa, soy bean, and cowpea, should be given for the first two years of the colt's life, for these hays are rich in lime, which is the principal ash element that is used in the making of bones. They are also rich in protein, which is needed for the production of muscle.

FEEDING BEEF CATTLE

The aim of every farmer who is not directly interested in dairying should be to keep enough beef cattle to consume and turn into money all cheap roughages, such as straws, corn stover, cheap hays, and the

grazing on waste-land areas. Cattle on Tennessee farms could be grown to the age of two years with a small expenditure of grain and at a much lower cost of production per pound than would be received for them. They could be sold at that age as feeders to corn-belt farmers who have cheaper feeds for finishing of cattle. Tennessee, and the South generally, should be a great feeder-cattle producing section on account of the abundance of cheap feeds.

Every farm in the State, where the farmer does not wish to specialize in dairying, should have a few beef cattle; and where the farmer wishes to keep only a few they should be milked. It is easily possible to build up small herds of beef cows in which the total production in milk per cow will exceed 4,000 pounds per year. The butter production from the cows would exceed 200 pounds per year without heavy feeding. The steers and heifers from such cows would be highly profitable, for a large amount of the feeds that they consume would otherwise be wasted. The butter fat would be too valuable to be given the calves by allowing them to suckle their dams. Experiments have shown that one cannot tell the difference between steers that have been allowed to suckle their dams and those that have been pail-fed at the same time that they are put in the feed-lot to be finished for the market.

Calves should not run with their dams more than 24 to 36 hours after birth. Take the calf away from the cow at night and put the cow where she cannot hear the calf. In the morning feed the calf from the bucket warm, fresh milk obtained from its mother. Pour only a small amount of the milk into a light bucket, then moisten the fingers with the milk and offer the calf the two middle fingers and force the calf's nose into the milk, and as the calf begins to drink, gradually remove the fingers. Two fingers must be placed in the calf's mouth in order that a channel may be formed for the passage of the milk between the fingers. If but one finger is offered, the calf will so wrap the tongue around the finger that no milk can be drawn into its mouth. Do not overfeed the calf. (For a rule for feeding milk to calves see page 58). Feed the calf from three to five times daily for the first few days, and later feed twice daily. As soon as the calf will take a little grain in the bottom of the bucket when licking it out this should be given. Drop into the bottom of the bucket a little grain of the following mixture: 3 parts whole corn, 3 parts whole oats, and 2 parts bran (parts always to be taken by weight). The calf will like whole grains better, and, besides, the grains need not be ground for calves of this age, for they thoroughly masticate their feed. Also calves receiving whole grains are said to be less subject to scours. The calf should always be given its feed in a stanchion, for it can be given its allowance of grain without interference from other calves. It should be left in the stanchion until the mouth is thoroughly dry;then there will be no desire to suckle the other calves ears and teats, which is a common source of scours infection. The

calf should be well fed until a year old. Cottonseed meal should not be fed to the calf until it is past ten months of age, at which time it will be taking a considerable amount of rough feeds, such as hay, which counteract the poison of meal. Even then it should not be fed in greater amounts per head per day than one pound.

During the second year the beef animal may be fed cheap feeds, such as straws, corn stover, and a little silage. Experiments at the Tennessee Experiment Station with the stocker cattle show that they should be so fed during the winter that they will make small gain in weight, in which case they would make considerable growth. Corn stover or straw, or a ration composed of the two with 1 to 2 pounds of cottonseed meal per head daily, makes a satisfactory ration for wintering stocker steers that are to be grazed during the following summer and finished for the block the next winter. Steers of that age should not be so fed that they make large gains, for two reasons: first, they cannot make use of the cheap feeds of the farm, such as corn stover and the straws; and secondly, the larger the winter gain, generally the smaller will be the summer gain. Experiments at the Tennessee Experiment Station, show, however, that where there is a loss in weight during the winter the total weight for the year of such steers is not as great as where they are so fed that they make a small gain during the winter. The experiments conducted thus far seem to indicate that the ideal to strive for is so to winter the stocker steers that they make a gain of from 50 to 80 pounds each during the winter.

There are several methods that may be successfully used in the wintering of stocker steers. A few good rations are as follows:

Ration 1:
Silage 15 lbs.
Straw 8 lbs.
Corn stover 8 lbs.
Cottonseed meal ½ lb.

Ration 2:
Silage 15 lbs.
Low-grade hay 10 lbs.

Ration 3:
Straw 10 lbs.
Cottonseed hulls 10 lbs.
Cottonseed meal 2 lbs.

Ration 4:
Corn stover cured in the shock, and then stacked when well-cured 20 lbs.
Cottonseed meal 2 lbs.

One of the best methods of wintering the stocker steer is to utilize winter-growing crops. During most of Tennessee winters, year-and-a-half-old cattle can pasture the greater part of the winter on such crops as wheat, rye, barley, crimson clover, and winter oats. Many successful feeders are wintering cattle on these crops during favorable weather and supplementing them with corn stover, straws, low-grade hays, and about one pound of cottonseed meal per head per day.

Another practice in feeding stocker steers in the State that has proved very successful is to winter the steers on a fairly good winter ration, and continue the ration while the steers are on grass, marketing

them during June with a fair amount of finish. When intended for market at that particular time of the year, they should receive during the winter a liberal ration of silage, with such cheap feeds as corn stover, straws, and a fair grain ration of 4 pounds of broken ear corn and 3 pounds of cottonseed meal. The grain ration should not be given until the latter part of the winter period. Hay should be given during the transition period from winter feeding to grass on account of the watery condition of the grass at this time, which makes the grass very laxative, and also because that grass has but a small amount of dry matter and therefore has a low food value.

The method of finishing cattle during the winter months depends upon several factors, the principal ones of which are the cost of feeds and the quality of steers to be finished. In the South corn is usually much higher in price than in the corn-belt states and the quality of the steers is usually lower. As a result, entirely different methods of finishing steers have been worked out. The quality of steers will oftentimes not pay for a high finish. When corn is high, cheaper feeds must be substituted. When steers are poor to fair in quality, less finish should be put on.

Corn may be used in the ration of the fattening steer when not too high priced. When used, the best practice seems to be to use cottonseed meal during the first 30 days, at the rate of 3 pounds per head per day, and then introduce corn into the ration during the second 30 days and third 30 days, with cottonseed meal reaching 4 pounds per head per day, and with corn beginning at 2 pounds per head per day and gradually increasing to 8 pounds. The roughage part of the ration should be made up of silage, oat straw, and barley straw. Bright, clean straws and well-cured shock-corn stover in such a system of feeding will give nearly as good results as hay.

Another method of finishing steers is that of using cottonseed meal or velvet bean meal as the sole grain ration. This has grown to be a common practice with Southern cattle feeders, and is being adopted by some Northern feeders. Experiments at the Tennessee Experiment Station indicate that the largest gain can be put on when cottonseed meal with silage or hulls is used, in the proportion of 5 to 7 pounds per head per day. The average daily gains where steers were fed in amounts increasing from 3 to 5 pounds of cottonseed meal per head per day was 1.52 pounds; where steers were fed in amounts increasing from 5 to 7 pounds the daily gain was 1.75 pounds; and where they were fed in amounts increasing from 7 to 9 pounds the daily gain was 1.72 pounds. Care should always be taken in getting steers on a full feed of cottonseed meal. Ten to fifteen days should be taken, with slight increase each day, to get the steers on a feed of 5 pounds per head per day. Where silage is fed, the cottonseed meal should be well mixed with the silage at the time of feeding. If velvet bean meal is used as the sole concentrate it may be fed in

amounts of about 10 pounds per head per day at the latter end of the finishing period.

The "fill" that is obtained on cattle when they are put into the feed lot during the fore part of the winter feeding period may be obtained largely with straws, stovers, and silage. In order to obtain the greatest advantage through the use of these cheap feeds the feeding of grain should not begin until the cattle have been on dry feed for twenty days.

Silage and cottonseed meal make it possible for the Tennessee farmer to compete in the raising of cattle and the finishing of steers with the corn-belt farmer. One of the best feeds that may be grown for cattle is corn silage. A 100-ton silo can be built for a money outlay of from \$80.00 to \$120.00. (Write for bulletin on silo). Experiments at the Tennessee Station with silage and cottonseed hulls as the roughage part of the ration, for finishing steers, proved that silage was more efficient than hulls. The average gain for the time on experiment of steers receiving silage and cottonseed meal was 154.9 pounds; hulls and cottonseed meal 144.1 pounds; and a combination silage, hulls and cottonseed meal 171.7 pounds. Whenever silage is fed, some dry feed should be fed along with it for best returns. Bright, clean straws are equally as efficient for that purpose as cottonseed hulls. Allowing that the manure offset the labor, and that the steers were fed on a \$1.50 margin and sold for \$7.00 per hundredweight, silage was worth, in Tennessee experiments, \$7.65 per ton. With hulls figured at \$8.00 per ton, silage at \$3.00 per ton, and cottonseed meal at \$25.00 per ton, the average profit on steers receiving hulls was \$7.28 and on steers receiving silage, \$11.28.

FEEDING DAIRY CATTLE

The products from dairy cattle are much more valuable than those from beef cattle, and hence more expensive feeds may be used. More hays and more grains may be used in the ration of the dairy cow. The cheaper roughages may be used for wintering the dry cows and yearlings. Silage should always be provided for the dairy animals, for larger yields of milk may be obtained through the use of this feed than any other kind.

The amounts of feed that should be given the dairy cow will vary with the kind. (For rule for feeding grain to the dairy cow, see page 57). While silage is an excellent feed, it should never make up the entire roughage ration. Ordinarily 30 pounds of silage per head per day should be considered a full feed for a 1000-pound dairy cow. The remainder of the roughage ration should consist for the most part of some legume hay, such as clover, alfalfa, soy bean, or cowpea. About 10 to 15 pounds of hay per day should be given. If more rough feed is needed, such feeds as bright, clean straws or well-cured shock-corn stover will prove appetizing and profitable. It never pays to feed less than a full feed to any kind of animals,

although the character of the ration may be adapted to the best practice for the kind to be fed.

The cheapest source of protein, where the protein feeds must be purchased, is cottonseed meal. An excellent grain ration for the dairy cow is 3 parts crushed corn-cob-and-shuck meal and 2 parts cottonseed meal. This ration may be given in the proportion of 1 pound for every 3 to 3½ pounds of milk until the amount of cottonseed meal reaches 4 pounds per head per day. If, according to this rule, more grain should be given, then some other kind of grain than cottonseed meal should be added to the ration. In that case barley, oats, or bran may be used. Another very good grain mixture is 4 parts crushed corn-cob-and-shuck meal, 2 parts cottonseed meal, and 2 parts cowpeas. In this ration 1 part soy beans may be substituted for the 2 parts cowpeas. For other grain rations, see page 104, or calculate a balanced ration according to methods outlined on pages 64 and 65.

The feeding of the dairy calf should be essentially the same as that recommended for the beef calf. (See pages 58 and 71).

If one desires to have a good, strong, vigorous dairy cow, it is best to develop a good, strong, vigorous dairy heifer. It does not pay to underfeed the dairy heifer. Do not turn the heifer on the stalk fields and allow her to shift for herself. Protection against storms and cold winds should be provided by means of good shed and barns, with well-battened sides, and good, bright, clean roughages, such as oat and barley straws, and well-cured shock-corn stover, with about 5 pounds of good hay and 1 to 2 pounds of cottonseed meal, should be given to the yearling heifers during the winter months. Ten to fifteen pounds of silage per head per day, or winter cover crops, may also be given in addition to the roughages just outlined.

The dairy heifer should be well developed until the time of dropping the first calf. Jersey heifers should be bred to drop calves at 24 months of age, Holsteins at 26 to 28 months of age. Jersey heifers may breed at 5 months of age. Hence aged and young bulls should not be allowed to run with the Jersey heifers that are 5 months of age or older.

Under general dairy-farm conditions the cows should freshen in the fall months. Dairy products of both milk and butter sell at better prices in winter than in summer. Dairy cows that freshen in the fall produce more milk and butter for the entire year than cows that freshen in the spring. Labor is more plentiful and cheaper in the winter months than in the summer months. There are more good reasons for having cows freshen in the fall than in the spring.

Do not allow the bull to run with the herd. Otherwise calves will arrive at all seasons of the year, and the lactation periods will be less than a year, which is not the most economical practice, for the freshening dates should be twelve months apart in order to give the maximum returns from the herd. It is better not to engage in the dairy business than to allow bulls to run with the herd.

FEEDING HOGS

The systems of feeding hogs in vogue today are inherited from the practices of our fathers, who used grain entirely for hogs. Corn and other grain were used exclusively because they were very cheap and were very profitably fed to hogs when cheap. With the prevailing high prices of grain, cheaper feeds for the hog must now be found.

An exclusive grain ration is not natural to the hog any more than it is to other kinds of farm animals. In the wild state hogs utilized such foods as roots, herbs, and succulent forage plants. Grain was eaten only when in season. Hogs will consume forage crops as

Throughout the Periods of Growth and Fattening Hogs Should Be Given Green Feed. Here the Hogs Are Shown Grazing on Oats.

well as will other farm animals if they are given an opportunity to do so. It is not true that grain forages are not good for hogs. Of course, green wheat or any other green feed will kill hogs just like it will any other kind of farm animals if they are kept in a dry lot throughout the winter and then are given unlimited access to an abundant supply of such feed. The fact that hogs will consume green feed enough to make them sick is evidence enough that they should be given it throughout the periods of growth and fattening. Green feeds are as essential for hogs as for other classes of animals, and if they are given a liberal supply of succulent forage crops they will make more profitable gains than almost any other kind of farm live stock. A straight corn ration is no more natural a feed for hogs than for any other class of farm animals.

One of the most common and mistaken opinions with regard to hogs is that they are the most unclean of farm animals. Hogs will keep their pens and yards cleaner than any other class of farm animals if they are given room enough to do so. There is no other class of farm animals that will set off one portion to sleep in, and another portion to feed in. The fact that hogs will wallow in mud is not an evidence that they are unsanitary; they do it rather as a sanitary measure. They do not by choice wallow in the unsanitary mud of the farmyards. If they could choose their place for wallowing in the mud they would select pools along the edges of streams that are practically free from the filth that is so common in the farmyard. Hogs wallow in the mud as a protection against lice and they lie in the edges of streams by choice when they can do so in order to keep cool. There are no sweat pores in the skin of the hog that will enable it to become cool through evaporation of moisture thrown out through the skin.

Streams of water are usually much cleaner than filthy wallow holes in barnyards. In hog cholera survey work conducted in 1914 by the U. S. Department of Agriculture, in 16 counties scattered throughout the United States, it was found that only 1.61 per cent of the outbreaks of hog cholera were traceable to contaminated streams; 23.1 per cent were traceable to exchanging labor and visiting infected premises; 17.27 per cent to birds; 8.42 per cent to exposure to sick hogs and adjoining farms; 9.57 per cent to dogs; and 4.58 per cent to other sources.

The best returns from hogs will always be obtained through feeding them a balanced ration. Since young hogs have a greater rate of growth than any other class of farm animals they need a greater supply of ash material. A little pig will multiply its birth weight by 10 in from 6 to 8 weeks. It takes from a year to a year and a half for colts and calves to multiply their birth weight by 10, and it takes a man from 10 to 12 years to multiply his birth weight by 10. The milk of the brood sow must necessarily be very rich in ash in order to meet the demands of Nature in supplying ash material to the young suckling pigs. Nature compels the sow to keep up a standard product of food for the young pigs. Therefore if ash is not supplied in the ration of the sow, with which she may supply ash in the milk that she secretes, she must supply the ash from the least used parts of her own body. Is it any wonder, then, when the sow is asked to supply milk rich in ash from a food low in ash, like corn, that she finally so weakens some of those parts that they break and we have on hand a "broken-down" sow? A straight corn ration is the most unbalanced ration imaginable for the sow that is suckling a large litter of pigs.

The remedy for a sow that has "broken down" is first to remove the cause. Wean the pigs; for there is little chance for a sow's recovery so long as she is required to produce milk, which is continually adding to the trouble through additional removal of the ash material

from her body, and so long as the little pigs worry the mother, which is already painfully sick. If tankage is obtainable it should be put into milk and given to the sow in quantities of ¼ pound per day. In three or four days it may be increased to ½ pound. This particular feed is rich in lime and phosphorus, which are the elements most needed to repair broken parts of the sow. The pigs must be carefully fed by hand on cow's milk. A couple of teaspoonfuls of tankage added to the ration of milk three times daily would also be good for the pigs.

Mineral matter (ash) may also be supplied to brood sows, growing pigs, and fattening hogs by the feeding of charcoal, wood ashes, air-slaked lime, ground bone, and salt. It is considered excellent practice to make a small pit 2 feet deep and 18 inches wide and rake the cobs from the feeding yard of the fattening hogs into it after first starting a fire in the bottom of the pit. After the fire is well started the pile should be covered with earth, with just enough opening at the top to keep the fire from smothering entirely. When the whole mass of cobs is on fire, the fire should be smothered entirely or the earth pulled away and wet down thoroughly. The hogs will greatly appreciate the cobs and will make better gains as a result of feeding on them. A very good mixture to keep before hogs as a condition powder, or to supply mineral water is the following:

Wood ashes 10 ℔s.	Air-slaked lime 3 ℔s.
Salt 2 ℔s.	Copperas 1 ℔.
Sulphur 1 ℔.	Charcoal 3 ℔s.

When hogs have worms, a very good mixture to keep before them is the following:

Glauber's salts 3 parts.	Sulphur 1 part.
Copperas 3 parts.	Salt 3 parts.
Sal Soda 3 parts.	Bran 3 parts.

Charcoal 6 parts.

Parts are always to be taken by weight. The above mixtures should be carefully mixed, on a good floor and then placed in boxes so that the hogs may have constant access to them. Where hogs are not accustomed to them they should be used in small quantities for the first few days, until the abnormal appetite of the hogs for them is satisfied. Where they are intended for pregnant brood sows the cooperas should be left out of each of the mixtures, as it is said to be harmful to sows in this condition.

If corn is used for the brood sow it should always be balanced with protein feeds. Likewise, better results are always obtained with corn for the fattening hogs when it is balanced with protein feeds. During the first thirty-six hours after farrowing, the brood sow

should be given no grain except a little bran mash in 2 quarts of milk at a feed. Water should, of course, be kept before her. More litters are perhaps ruined through overfeeding of the brood sow during the first thirty-six hours after farrowing than in any other way. The sow is feverish. Feed makes her more feverish. She is sluggish. Full feeding makes her more sluggish; and she is not careful with the pigs or heedful to their cries when lain upon. She should be fed very lightly during the first week. After that a very good practice is to feed all that the sow will clean up, with good appetite, of a mixture of grains, as in the following rations:

Ration 1:
- Corn 4 parts.
- Barley 2 parts.
- Oats 2 parts.
- Soy beans 2 parts or cowpeas 4 parts.

Ration 2:
- Corn 3 parts.
- Barley 3 parts.
- Oats 3 parts.
- Soy beans 2 parts or cowpeas 4 parts.

Ration 3:
- Corn 1 part.
- Skimmilk or buttermilk 3 parts.

Ration 4:
- Corn 6 parts.
- Barley 3 parts.
- Tankage 1 part.

The sow and pigs would do best if given, in addition to the above, all the green feed that they would eat, such as alfalfa, clover and soy bean forages in season, and winter cover crops, such as barley and crimson clover, wheat, rye, and oats in season.

The fattening hog being finished on corn should always receive some protein supplement to the ration. Any one of the following supplements may be given to 150- to 250-pound hogs in the amounts recommended. No more than one should be given at a time in this amount, along with corn:

Cottonseed meal ½ to 1 pound per head per day.
Tankage ¼ to ½ pound per head per day.
Soy beans ½ to 1 pound per head per day.
Cowpeas 1 to 1½ pounds per head per day.
Skimmilk or buttermilk 3 to 4 quarts per head per day.

Cottonseed meal may be used for the last three weeks in balancing the corn ration fed to hogs intended for market, with no danger of poisoning. Where cottonseed meal is to be used in the ration for a period longer than three weeks, copperas should be fed with it to neutralize its detrimental effects. A solution of copperas should be made up in the proportion of 4 pounds of copperas to 50 gallons of water. A quart of this solution should be fed for every pound of cottonseed meal.

Hogs should be grown and finished on forage crops whenever possible. Forage alone is but little more than a maintenance ration, but when supplemented with grain will produce pork more cheaply than any other feed. Forage crops also have the advantage of allowing for the retention of the greatest amount of fertilizing constituents of the feeds fed on the lands. (See Table IV, also Table V, in the Appendix). It is a good general rule for feeding grain to hogs on forage crops, to feed to the growing shotes 2½ per cent of their live weight per day. If the forage is abundant the grain ration may consist almost entirely of corn, although the addition of ½ pound of soy beans or ½ pound of cowpeas will prove profitable. Tankage may be used at the rate of ¼ pound daily. During the finishing period they should of course be given a full feed of corn, supplemented with protein feeds, as outlined above.

The number of hogs that should be put on each acre will depend upon the nature of the forage. Ordinarily ten to twelve 100- to 150-pound shotes per acre are enough. Forage crops for hogs should not be pastured too closely. Forage crops that are best suited to hogs for summer pastures are alfalfa, red clover, soy beans, Lespedeza clover, blue grass, a mixture of rape, oats and clover, and sorghum if pasturing is begun when 6 inches high. Forage crops best suited for winter forage are crimson clover, barley, wheat, rye, and winter oats. Combinations of these crops may easily be made, so that there will be a continuous succession of succulent forages for the hogs.

FEEDING SHEEP

Sheep are the most profitable animals that may be kept on the farm; yet it does not follow that there should be large flocks of sheep on Tennessee farms, because when kept in large numbers they are not nearly so profitable. Small flocks of sheep should be kept on every farm. A few sheep on the farm would consume feed that would otherwise go to waste. A few sheep, say an average-sized flock of ten ewes, would represent almost clear profit on the average Tennessee farm. A small flock could be put on the wheat in winter without damage to it; could be put on barley and crimson clover in the spring, or on blue grass; could be turned into the cornfield to eat weeds that the cultivator had missed, and to eat grass along the fence around the cornfield; could be turned on the wheat stubble after the wheat was taken off; could be turned on the soy bean field or in the cowpea field; and, in fact, could be turned into many places on the farm to gather feed that would otherwise be wasted.

Where small flocks are kept, the fleece of wool would more than pay for the cost of keep of the ewe and lamb for the entire year. Each lamb, if dropped in January, should be marketed in May or June at a weight of 90 pounds, and sell at from 8 to 11 cents per pound. In other words, every ewe on the farm should bring in a clear profit

of from \$7.00 to \$8.00, when one lamb is produced, and more than that when two lambs are produced. A small flock of ten ewes should bring in a profit to the farm of from \$70 to \$100.

When the lambs are marketed the ewes should be put on short pasture for a few days until the milk flow ceases. Give the flock special attention at this time, for often the best ewes in the flock are ruined for lack of attention to the udder. After the lambs have been removed for twelve hours, drive the flock into a small pen and examine the udders. Milk out enough to relieve the tension from the udders that are much distended. The operation should be repeated again in another twelve hours. Usually further attention will not be needed. It is the very best ewes, giving the most milk, that give trouble.

The ewe flock should be kept on rather poor pasture until the first of August, when they may be turned on extra good pasture, such as a good meadow field that has been reserved for them until this time. Any pasture that is especially good at this time may be used for the ewe flock. The practice of keeping ewes on poor pasture for the period intervening between lamb-weaning time and the breeding season, and then putting them on very good pasture, is known as "flushing". It may likewise be accomplished by giving the ewes grain during the mating season. Experiments on the flushing of ewes show that they will come into season earlier, and all at nearly the same time, and that a larger number of twins will be produced. The theory of flushing is that the increase of laxative, cooling food will cause a sudden stimulation in health of the ewe, that the cells of the body will be suddenly multiplied, and that the reproductive cells will become more active. If the flock has been kept on good pasture it is not easy to flush them.

The ram should be so cared for as to be in the very best condition at the breeding season. He should be kept separate from the flock, on the very best of pasture, during the summer months. In order to have good, strong lambs, the ram should be in good, strong, vigorous condition at the breeding season. It is exceedingly good practice to exchange rams with a neighbor four weeks after the beginning of the breeding season. For one reason or another, rams sometimes become impotent, and the exchange of rams with a neighbor insures a crop of lambs for both flocks.

The ewes for the production of early lambs may be mountain or common ewes, but the ram should be a purebred ram of one of the black-faced breeds. Southdown, Shropshire, Hampshire, Suffolk, or Oxford rams should be used for the production of early lambs. Black-faced lambs have gained such a reputation on the market that the trademark of a black face helps to sell the lamb. Dorset Horned lambs also sell well on the market.

If the ewes are in good condition at the beginning of the winter season they will need no grain. If they are not in good condition they should be given ¼ to ½ pound of cottonseed meal. Unless the weather

is very unfavorable, they may pasture for most of the winter on cover crops. In fact, cover crops of some kind should be provided for the ewe flock.

If the breeding season has been successful most of the lambs will come during the second and third weeks of January, and not be scattered over a long period of time. Special attention should be given the flock at this time, for the loss of a lamb means the loss of profit from a ewe for the year. The flock should be visited several times a day in order that the ewes that are lambing may be cared for. An ideal shelter for the flock at this time would be a shed tightly closed on three sides and with one side open to the south. If the ewe does not make any progress toward the delivery of a lamb after an hour and a half of labor, an investigation should be made and some assistance given. It is best to keep the ewes on a well-drained blue-grass lot during the lambing season. The grain fields are likely to be too wet. After a ewe lambs, she may be put into the grain field.

If the pasture is abundant the ewes will need no grain. Where convenient, the lambs should be provided with a "creep",* where they may be fed a grain ration composed of equal parts of shelled corn and oats.

FEEDING POULTRY

The poultry of the farm suffer more neglect in the matter of feeding than any other of the farm live stock. The eggs they produce are richer in protein than any other live stock product. If protein is not supplied in the ration of the laying hen she cannot be expected to lay, for she must have plant protein in order to make animal protein. Such feeds as corn, barley, and oats are low in protein and should be balanced with such feeds as soy beans, cottonseed meal, cowpeas, milk, and meat scrap. A very good grain mixture for laying hens on Tennessee farms that may be made almost entirely from home-grown feeds is—

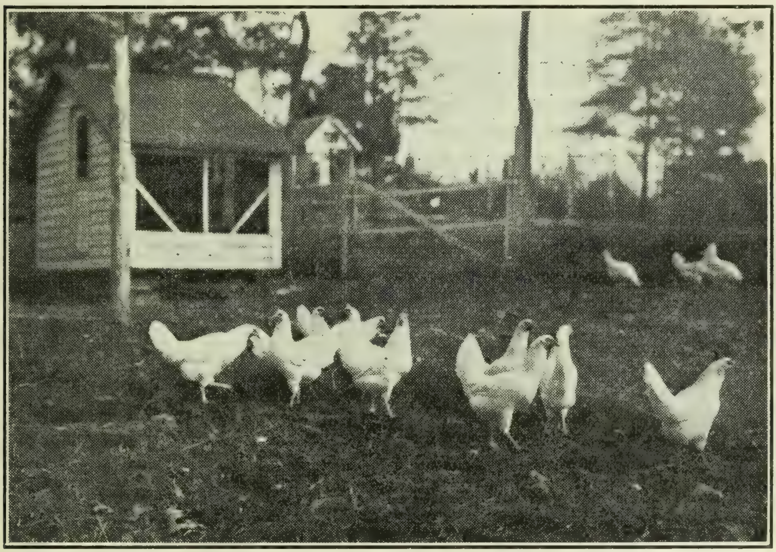
Corn 6 parts.
Barley 6 parts.
Wheat 4 parts.
Oats 4 parts.
Soy beans 2 parts.
Cottonseed meal 2 parts.

Skimmilk should be given in addition to the above mixture, at the rate of 2 pounds of skimmilk for every pound of the mixture. It would

*A lamb creep is a small pen with vertical openings wide enough to admit of the entrance of the lambs but not the mother ewes. When they are made in the corner of the field, covered troughs should be used so as to keep the feed troughs dry. The more rapid gains will more than pay for the feed given them. Put into the troughs only as much as they will clean up from one feed to another.

be well for a third of the above mixture to be ground and fed in the morning, in the form of a mash. A little of the whole grain could also be fed in the morning, in the litter, in order to provide exercise for the hen during the day, and the remainder of the ration fed in the late afternoon. Such a mixture of grains would be equally as efficient as commercial poultry foods and would cost much less, for it could be compounded on the farm. Not so many grains in the ration are necessary but are advisable because better results are always had where there is plenty of variety of feed stuffs in the ration.

Meat meal may be used in the above ration where it can be easily obtained, but where skimmilk is plentiful it is not necessary. Ground green bone is also highly beneficial where it can be obtained.



Don't Neglect the Hens. They Need Good Feed and Will Respond to It With a Cash Income for the Farmer. This Bulletin Tells What Tennessee Farmers Can Feed With Profit.

Care must be taken to provide plenty of material for the making of shells. If there are soft-shelled eggs, it is an indication that enough lime is not being supplied in the ration. Crushed lime rock is equally as beneficial as broken oyster shell.

The little chicks will need finer feed than the mature fowls. Food should not be given them for at least 24 hours after hatching. Some poultrymen do not feed chicks until 72 hours after hatching.

There is possibly a little less mortality when dry foods are given to the young chicks. The following mixture makes a fairly well-balanced ration for the young chicks:

Equal parts of—

Rolled or pin-head oats.
Cracked wheat.
Cracked barley.
Cracked buckwheat.
Cracked kafir corn.
Millet seed.

In a short time wheat may be given whole. Screenings are good for half-grown chicks, and the oats may be simply hulled and the corn more coarsely cracked.

Cottage cheese or clabbered milk is excellent for the growing chicks. They are much less subject to diarrhea when receiving it.

A very good bread for chicks is made by baking a dough made of the following ingredients:

Bran 2 quarts
Coarse corn meal 2 quarts
Wheat middlings 1 quart
Beef scrap 1 handful
Finely broken limestone 1 handful

Rub together dry with from 2 to 4 eggs. Those eggs that have been found infertile at the end of the first week may be used. Mix with barley enough skimmilk to moisten, and rub the whole into a crumbly mass. Put into a 3-inch-deep pan, press down hard, and bake in a slow oven from 3 to 6 hours. When finished there should be no stickiness or doughiness.

Salt is a necessity for fowls. Eggs are rich in salt elements and salt is necessary for the best health of the fowl. Fowls regularly accustomed to salt are not likely to eat an injurious quantity when it is accidentally left within their reach. A little salt should be given every day in the ration of the fowls.

APPENDIX

Tables for Men Who Feed Live Stock

On the pages that follow will be found information that can be used by any Tennessee feeder of live stock. For the information in the long tables the writer is indebted to Henry and Morrison, "Feeds and Feeding."

Use the facts that these tables give you to make your feeding easier and more profitable.

Money can be made from live stock properly fed and cared for. Let the pages of this bulletin help you.

TABLE I—*Average percentage composition of American feeding stuffs*

FEEDING STUFF	Water	Ash	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
CONCENTRATES AND THEIR BY-PRODUCTS	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Corn and its products						
Dent corn	10.5	1.5	10.1	2.0	70.9	5.0
Flint corn	12.2	1.5	10.4	1.5	69.4	5.0
Sweet corn, mature	9.3	1.8	11.5	2.3	67.2	7.9
Corn meal or chop	11.3	1.3	9.3	2.3	72.0	3.8
Corn cob	10.0	1.5	2.0	31.8	54.3	0.4
Corn-and-cob meal	10.4	1.5	8.5	7.9	67.6	4.1
Hominy feed, high grade	10.1	2.6	10.6	4.4	64.3	8.0
Gluten feed, high grade	8.7	2.1	25.4	7.1	52.9	3.8
Gluten meal, high grade	9.1	1.1	35.5	2.1	47.5	4.7
German oil meal, high grade	8.9	2.7	22.6	9.0	46.0	10.8
Corn bran	10.0	2.4	9.7	9.8	62.4	5.7
Wheat and its products						
Wheat, all analyses	10.2	1.9	12.4	2.2	71.2	2.1
Winter wheat	10.9	1.8	11.7	2.0	71.6	2.0
Standard wheat middlings (shorts)	10.5	4.4	17.4	6.0	56.8	4.9
Wheat bran, all analyses	10.1	6.3	16.0	9.5	53.7	4.4
Wheat feed (shorts and bran)	10.1	5.2	16.8	7.6	55.7	4.6
Wheat screenings	10.2	3.9	13.3	7.4	61.1	4.1
Rye and its products						
Rye	9.4	2.0	11.8	1.8	73.2	1.8
Rye middlings	11.4	3.7	15.7	4.6	61.2	3.4
Rye bran	11.4	3.5	15.3	4.0	62.7	3.1
Rye feeds (shorts and bran)	11.5	3.8	15.3	4.7	61.5	3.2
Oats and oat products						
Oats	9.2	3.5	12.4	10.9	59.6	4.4
Oat meal	7.9	2.0	16.0	1.5	66.1	6.5
Oat feed, low grade	10.2	4.0	9.6	18.5	53.8	3.9
Oat hulls	6.8	6.0	4.0	29.2	52.3	1.7
Barley, its products, and emmer						
Barley	9.3	2.7	11.5	4.6	69.8	2.1
Brewers' grains, dried	7.5	3.5	26.5	14.6	41.0	6.9
Brewers' grains, wet	75.9	1.0	5.7	3.6	12.1	1.7
Rice and its products						
Rough rice	9.6	4.9	7.6	9.3	66.7	1.9
Rice polish	10.0	4.8	11.9	1.9	62.3	9.1
Rice bran, high grade	10.1	9.7	12.1	12.4	44.3	11.4
Rice meal	9.5	9.1	11.8	9.3	48.7	11.6
Rice hulls	9.3	16.9	3.3	35.4	34.0	1.1
Buckwheat and its products						
Buckwheat	12.1	2.1	10.8	10.3	62.2	2.5
Buckwheat middlings	12.0	4.8	28.3	4.8	42.7	7.4
Buckwheat bran, high grade	11.2	4.2	22.3	7.1	49.4	5.8

TABLE I—*Continued*

FEEDING STUFF	Water	Ash	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Buckwheat feed, good grade	11.8	4.4	19.3	17.9	41.4	5.2
Buckwheat hulls	10.3	2.1	4.4	43.7	38.5	1.0
The Sorghums						
Kafir grain	11.8	1.7	11.1	2.3	70.1	3.0
Kafir-head chops	12.5	2.8	9.7	6.4	65.9	2.7
Milo grain	10.7	2.8	10.7	2.4	70.5	2.9
Milo head chops	10.3	3.1	10.10	5.9	68.1	2.6
Feterita grain	10.8	1.5	11.5	1.2	71.7	3.3
Kaoliang grain	9.9	1.9	10.5	1.5	71.9	4.3
Sorghum grain	12.7	1.9	9.2	2.0	70.8	3.4
Broom-corn seed	11.8	2.9	10.2	8.2	63.5	3.4
Cottonseed and its products						
Cottonseed	9.4	4.6	19.5	22.6	24.9	19.0
Cottonseed meal, choice	7.5	6.2	44.1	8.1	25.0	9.1
Cottonseed meal, prime	7.8	6.6	39.8	10.1	27.4	8.3
Cottonseed meal, good	7.9	6.4	37.6	11.5	28.4	8.2
Cold-pressed cottonseed cake	7.9	4.2	26.1	24.0	30.1	7.7
Cottonseed hulls	9.7	2.7	4.6	43.8	37.3	1.9
Cottonseed-hull bran	8.4	2.5	3.4	34.8	49.7	1.2
Flaxseed and its products						
Linseed meal, new process	9.6	5.6	36.9	8.7	36.3	2.9
Legume seeds and products						
Bean, navy, cull	12.8	3.3	22.1	3.7	56.7	1.4
Cowpea	11.6	3.4	23.6	4.1	55.8	1.5
Horse bean	12.6	3.8	26.2	7.1	49.4	0.9
Pea, field	9.2	3.4	22.9	5.6	57.8	1.1
Peanut, with hull	6.5	4.1	20.4	16.4	16.4	36.2
Peanut cake, from hulled nuts	10.7	4.9	47.6	5.1	23.7	8.0
Peanut cake, hulls included	5.6	4.5	28.4	23.4	27.0	11.1
Peanut hulls	9.1	5.5	7.3	56.6	18.9	2.6
Soy bean	9.9	5.3	36.5	4.3	26.5	17.5
Soy bean meal, fat extracted	11.8	5.4	41.4	5.3	28.7	7.4
Velvet bean, seed and pod	12.3	4.0	17.1	14.3	47.7	4.6
Velvet bean, seed	11.7	2.6	20.8	7.5	51.0	6.4
Rapeseed cake	10.0	7.9	31.2	11.3	30.0	9.6
Sunflower seed, without hulls	4.5	3.8	27.7	6.3	16.3	41.4
Milk and its products						
Cow's milk	86.4	0.7	3.5	-----	5.0	4.4
Skim milk, centrifugal	90.1	0.7	3.8	-----	5.2	0.2
Skim milk, dried	8.3	25.1	36.6	-----	25.8	4.2
Buttermilk	90.6	0.7	3.6	-----	5.0	0.1
Whey	93.4	0.7	0.8	-----	4.8	0.3
Mare's milk	90.6	0.4	2.0	-----	5.9	1.1
Ewe's milk	80.8	0.9	6.5	-----	4.9	6.9

TABLE I—*Continued*

FEEDING STUFF	Water	Ash	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Sow's milk	81.0	1.0	5.9	-----	5.4	6.7
Slaughterhouse by-products						
Dried blood	9.7	3.3	82.3	-----	3.8	0.9
Fish meal, high in fat	10.8	29.2	48.4	-----	-----	11.6
Fresh bone	30.4	21.1	19.7	-----	3.8	25.0
Meat-and-bone meal, 30-40% ash	6.0	36.8	39.8	2.1	4.1	11.2
Pork cracklings	5.0	2.3	56.4	-----	4.1	32.2
Tankage, 55-60% protein	7.5	13.6	58.1	4.9	2.9	13.0
Miscellaneous concentrates						
Acorn, kernel and shell	27.9	1.1	3.4	17.8	45.4	4.4
Beet pulp, dried	8.2	3.5	8.9	18.9	56.6	0.9
Beet pulp, molasses	7.6	5.6	9.5	15.9	60.7	0.7
Chess, or cheat, seed	7.7	4.1	10.5	7.2	68.8	1.9
Distillers' grains, dried, from corn	6.6	2.6	30.7	11.6	36.3	12.2
Distillers' grains, dried, from rye,	7.2	3.9	23.1	10.9	47.1	7.8
Molasses, beet	25.3	5.2	3.5	-----	66.0	-----
Molasses, cane, or blackstrap	25.8	6.4	3.1	-----	64.7	-----
Starch feed, dry	9.3	1.8	15.4	7.2	59.4	6.9
Starch refuse	10.3	1.6	6.3	7.3	73.1	1.4
DRIED ROUGHAGE						
Cured corn, sorghum forage, etc.						
Corn fodder (ears, if any remaining) very dry, from barn or in arid districts	9.0	6.5	7.8	27.2	47.3	2.2
Corn fodder, medium in water	18.3	5.0	6.7	22.0	45.8	2.2
Sweet corn fodder	12.3	9.0	9.2	26.4	41.3	1.8
Corn stover (ears removed), very dry	9.4	5.8	5.9	30.7	46.6	1.6
Corn stover, medium, in water	19.0	5.5	5.7	27.7	40.9	1.2
Corn husks	24.7	2.5	2.9	24.9	44.2	0.8
Corn stalks	17.7	5.2	4.8	27.8	43.1	1.4
Kafir fodder, dry	9.0	9.4	8.9	26.8	43.1	2.8
Kafir stover, dry	16.3	8.3	5.1	27.4	41.2	1.7
Milo fodder, dry	11.1	9.9	12.0	18.4	44.1	4.5
Sorghum fodder, dry	9.7	7.8	7.4	26.1	45.9	3.1
Sorghum bagasse, dried	11.3	2.9	3.4	30.5	50.5	1.4
Broom-corn fodder	9.4	5.7	3.9	36.8	42.4	1.8
Sugar-cane bagasse	10.2	5.6	3.3	34.6	39.2	7.1
Hay from the grasses, etc.						
Bent grass, Canada or blue joint	6.7	6.8	7.6	34.7	41.8	2.4
Bermuda grass	9.7	7.6	7.1	25.6	48.2	1.8
Bluegrass, Canada	10.7	5.8	6.6	28.2	46.4	2.3
Bluegrass, Kentucky, all analyses	13.2	6.6	8.3	28.3	40.7	2.9
Brome grass, smooth	8.5	7.7	9.9	31.3	40.2	2.4

TABLE I—*Continued*

FEEDING STUFF	Water	Ash	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Bluestem grasses	6.9	5.5	4.9	34.2	46.7	1.8
Carpet grass	7.9	10.2	7.0	31.8	40.9	2.2
Chess, or cheat	8.4	7.9	7.2	28.0	46.2	2.3
Crab grass	9.5	8.5	8.0	28.7	42.9	2.4
Crowfoot grass	9.5	7.9	8.6	27.4	44.4	2.2
Fescue, meadow	11.7	7.0	6.8	30.4	42.1	2.0
Fowl meadow grass	11.1	7.2	9.8	28.8	40.4	2.7
Foxtails, miscellaneous	6.8	10.1	9.3	28.6	42.6	2.6
Johnson Grass	10.1	7.5	6.6	30.2	43.5	2.1
Millet, barnyard	13.5	8.2	8.3	27.6	40.8	1.6
Millet, common or Hungarian	14.3	6.3	8.3	24.0	44.3	2.8
Millet, German	8.7	6.9	8.0	27.3	46.5	2.6
Mixed grasses	12.8	5.6	7.6	28.8	42.7	2.5
Mixed grasses, rowen	13.6	6.5	12.3	24.2	40.1	3.3
Oat grass, tall, or meadow oat grass	11.8	6.1	8.0	29.4	42.1	2.6
Old witch grass	7.1	10.1	10.6	24.3	45.7	2.2
Orchard grass	11.6	6.9	7.9	30.3	40.4	2.9
Prairie hay, western	6.5	7.7	8.0	30.5	44.7	2.6
Quack, or couch grass	5.9	7.3	7.3	36.5	40.1	2.0
Red top, all analyses	9.8	6.8	7.4	28.7	45.0	2.3
Rye grass, perennial	12.0	8.1	9.2	24.2	43.4	3.1
Sedges, eastern	9.3	7.4	6.1	29.2	46.3	1.7
Sweet vernal grass	9.3	9.3	12.4	21.7	42.7	4.6
Timothy, all analyses	11.6	4.9	6.2	29.9	45.0	2.5
Wheat grass, common	7.3	6.9	6.5	27.4	49.4	2.5
Wild oat	7.9	6.4	8.0	30.1	44.8	2.8
Wild barley, or foxtail	7.5	8.8	7.0	27.4	47.3	2.0
Hay from the smaller cereals						
Barley hay, common	7.4	6.4	7.0	29.7	47.3	2.2
Oat hay	12.0	6.8	8.4	28.3	41.7	2.8
Rye hay, all analyses	8.1	5.1	6.7	37.5	40.5	2.1
Wheat hay	8.1	6.4	6.2	24.7	52.6	2.0
Hay from the legumes						
Alfalfa, all analyses	8.6	8.6	14.9	28.3	37.3	2.3
Alfalfa, first cutting	8.5	8.8	13.9	30.9	36.2	1.7
Alfalfa, second cutting	7.3	9.0	14.7	31.9	35.4	1.7
Alfalfa, third cutting	8.9	9.5	14.6	28.4	36.8	1.8
Alfalfa, fourth cutting	16.0	7.8	15.9	24.6	34.0	1.7
Alfalfa meal	8.8	9.0	14.3	30.1	35.8	2.0
Bean, whole plant	12.6	3.5	22.5	4.4	55.2	1.8
Beggarweed	9.1	8.4	15.4	27.5	37.3	2.3
Clover, alsike, all analyses	12.3	8.3	12.8	25.7	38.4	2.5
Clover, bur	7.0	10.8	19.2	23.0	37.0	3.0
Clover, crimson, or scarlet	10.6	8.8	14.1	27.3	36.9	2.3

TABLE I—*Continued*

FEEDING STUFF	Water	Ash	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Clover, mammoth red	18.7	6.2	10.8	27.0	34.2	3.1
Clover, red, all analyses	12.9	7.1	12.8	25.5	38.7	3.1
Clover, sweet, white	8.6	7.2	14.5	27.4	40.1	2.2
Clover, white	8.1	8.0	16.2	23.2	41.6	2.9
Clover meal	8.5	7.2	13.7	25.9	42.4	2.3
Clover, rowen	14.8	7.3	16.5	20.4	37.3	3.7
Cowpea, all analyses	9.7	11.9	19.3	22.5	34.0	2.6
Kudzu vine	7.1	6.8	16.7	25.0	41.2	3.2
Lespedeza, or Japan clover	11.8	5.8	12.1	25.9	41.6	2.8
Pea, field	11.1	7.9	15.1	24.5	37.9	3.5
Peanut vine, without peanuts	21.5	8.7	9.1	20.2	36.8	3.7
Soy bean hay	8.6	8.6	16.0	24.9	39.1	2.8
Trefoil, yellow, or black medic	11.2	10.9	16.9	14.8	43.2	3.0
Velvet bean	7.2	7.4	16.4	27.5	38.4	3.1
Vetch, common	7.1	8.2	17.3	26.2	38.7	2.5
Vetch, hairy	12.3	8.6	19.9	24.8	31.6	2.8
Hay, mixed legumes and grasses						
Clover and timothy	12.2	6.1	8.6	29.9	40.8	2.4
Straw and chaff from cereals						
Barley straw	14.2	5.7	3.5	36.0	39.1	1.5
Buckwheat straw	9.9	5.5	5.2	43.0	35.1	1.3
Oat straw	11.5	5.4	3.6	36.3	40.8	2.4
Oat chaff	8.2	11.5	5.9	25.7	46.3	2.4
Rice straw	7.5	14.5	3.9	33.5	39.2	1.4
Rye straw	7.1	3.2	3.0	38.9	46.6	1.2
Wheat straw	8.4	5.2	3.1	37.4	44.4	1.5
Wheat chaff	14.4	7.2	4.2	28.0	44.8	1.4
Legume straws						
Bean stover	10.5	7.2	7.3	30.8	42.9	1.3
Cowpea stover	8.5	5.4	6.8	44.5	33.6	1.2
Soy bean stover	11.9	6.8	5.6	36.8	37.2	1.7
Miscellaneous dry roughages						
Sweet potato vines	11.3	9.2	12.5	20.2	43.5	3.3
FRESH GREEN ROUGHAGE						
Corn and the sorghums						
Corn fodder, all anlayses	78.1	1.2	1.9	5.2	13.0	0.6
Sweet corn fodder, ears removed	78.5	1.3	1.6	5.6	12.6	0.4
Corn stover, green (ears removed)	77.3	1.4	1.3	6.0	13.6	0.4
Kafir fodder, all analyses	76.4	1.9	2.4	6.6	12.0	0.7
Sweet sorghum fodder	75.1	1.4	1.5	7.0	14.0	1.0
Sugar cane	78.3	1.4	0.9	6.2	12.2	1.0
Fresh green grass						
Bermuda grass	66.8	2.3	3.0	8.0	18.9	1.0
Bluegrass, Canada	66.8	2.6	3.0	10.3	16.1	1.2

TABLE I—*Continued*

FEEDING STUFF	Water	Ash	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Bluegrass, Kentucky, all analyses	68.4	2.8	4.1	8.7	14.8	1.2
Chess, or cheat	60.4	1.8	3.2	13.0	20.5	1.1
Crab grass	69.1	4.3	2.7	9.1	13.8	1.0
Fescue, meadow	69.5	2.4	3.0	10.1	14.0	1.0
Johnson grass	70.9	2.0	2.5	9.3	14.4	0.9
Meadow foxtail	70.4	2.7	3.6	8.0	14.1	1.2
Millet, barnyard	78.7	1.6	1.7	6.7	10.7	0.6
Millet, common, or Hungarian	72.4	2.1	2.9	8.4	13.3	0.9
Oat grass, tall, or meadow oat grass	69.7	2.0	2.6	10.5	14.3	0.9
Orchard grass	70.8	2.5	2.9	9.8	12.9	1.1
Quack grass	75.0	2.5	3.8	7.0	10.5	1.2
Red top	60.7	2.7	3.1	12.2	20.2	1.1
Rye grass, perennial	73.4	2.4	3.0	6.7	13.2	1.3
Sweet vernal grass	68.8	2.0	2.6	9.7	15.9	1.0
Timothy, all analyses	62.5	2.2	3.1	11.7	19.3	1.2
Wild barley, or foxtail	64.3	3.5	4.9	11.8	14.1	1.4
Green fodder, the smaller cereals						
Barley fodder	76.8	2.1	3.3	6.0	11.0	0.8
Oat fodder	73.9	2.1	3.2	7.8	11.9	1.1
Rye fodder	78.7	1.7	2.6	7.3	9.0	0.7
Wheat fodder, all analyses	72.6	2.7	3.6	7.5	12.8	0.8
Green legumes						
Alfalfa, all analyses	74.7	2.4	4.5	7.0	10.4	1.0
Clover, alsike	75.7	2.2	3.5	5.9	9.3	0.6
Clover, bur	79.2	2.3	5.1	3.9	7.8	1.7
Clover, crimson	82.6	1.7	3.0	4.7	7.4	0.6
Clover, mammoth red	74.9	2.3	4.0	7.3	11.0	0.5
Clover, red, all analyses	73.8	2.1	4.1	7.3	11.7	1.0
Clover, sweet	75.6	2.1	4.4	7.0	10.2	0.7
Clover, white	78.2	2.7	4.6	4.2	9.5	0.8
Cowpeas	83.7	2.0	3.0	3.8	7.0	0.5
Peas, field, Canada	83.4	1.6	3.6	4.0	6.9	0.5
Kudzu vine	69.4	2.2	5.5	8.3	13.6	1.0
Lespedeza, or Japan clover	63.4	3.5	6.7	10.7	14.7	1.0
Soy beans, all analyses	76.4	2.4	4.1	6.3	9.8	1.0
Soy beans, in bloom	79.2	2.3	3.9	5.8	8.2	0.6
Soy beans, in seed	75.8	2.4	4.0	6.4	10.4	1.0
Velvet bean	82.1	2.0	3.5	5.1	6.6	0.7
Vetch, common	79.6	2.1	3.8	5.5	8.5	0.5
Vetch, hairy	81.8	2.2	4.2	5.0	6.3	0.5
Mixed legumes and grasses						
Clover and mixed grasses	72.7	1.6	3.0	8.5	13.3	0.9
Cowpeas and corn	80.0	1.8	2.1	5.3	10.4	0.4
Soy beans and corn	76.2	1.7	2.7	5.4	13.2	0.8

TABLE I—*Continued*

FEEDING STUFF	Water	Ash	Crude protein	Carbohydrates		Fat
				Fiber	N-free extract	
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Vetch and barley	80.0	1.2	2.8	6.5	9.0	0.5
Vetch and wheat	77.3	1.6	3.3	7.1	10.1	0.6
Roots, tubers, etc.						
Artichoke	79.5	1.7	2.0	0.8	15.9	0.1
Beet, sugar	83.6	1.1	1.6	1.0	12.6	0.1
Carrot	88.3	1.2	1.2	1.1	8.0	0.2
Cassava	67.4	1.0	1.1	1.4	28.8	0.3
Chufa	79.5	0.4	0.7	2.2	10.5	6.6
Mangel	90.6	1.0	1.4	0.8	6.1	0.1
Potato	78.8	1.1	2.2	0.4	17.4	0.1
Rutabaga	89.1	1.0	1.2	1.4	7.0	0.3
Sweet potato	68.8	1.1	1.8	1.3	26.4	0.6
Turnip	90.5	0.9	1.4	1.1	5.9	0.2
Miscellaneous green forages						
Apple	81.8	0.4	0.5	1.3	15.6	0.4
Apple pomace	76.7	1.0	1.6	4.6	14.5	1.6
Cabbage	91.1	0.8	2.2	0.9	4.7	0.3
Pumpkin, field	91.7	0.9	1.4	1.3	4.2	0.5
Rape	83.3	2.2	2.9	2.6	8.4	0.6
Sugar beet leaves	88.4	1.8	1.9	1.1	6.5	0.3
Turnip tops	85.0	3.0	2.8	1.5	7.3	0.4
SILAGE						
From corn, the sorghums, etc.						
Corn, well matured, recent analyses	73.7	1.7	2.1	6.3	15.4	0.8
Corn, immature	79.0	1.4	1.9	5.8	11.3	0.6
Corn, from frosted corn	74.7	1.8	2.2	6.1	14.4	0.8
Corn, from field-cured stover	80.4	1.4	1.4	6.3	9.8	0.7
Sorghum, sweet	77.2	1.6	1.5	6.9	11.9	0.9
Sugar-cane tops	76.6	1.9	1.3	8.0	11.8	0.4
Miscellaneous silage						
Alfalfa	75.4	2.9	3.5	8.2	8.6	1.4
Apple pomace	79.4	1.0	1.6	4.5	12.2	1.3
Clover	72.2	2.5	3.7	9.0	11.5	1.1
Corn and clover	71.4	2.2	3.3	7.7	14.5	0.9
Corn and soy bean	75.3	2.0	2.5	6.7	12.5	1.0
Cowpea	78.0	2.2	3.2	6.3	9.4	0.9
Pea-cannery refuse	76.8	1.3	2.8	6.5	11.3	1.3
Soy bean	72.9	3.5	3.9	8.1	10.3	1.3
Wet brewers' grains	70.2	1.2	6.4	4.5	15.6	2.1

TABLE II—*Average digestible nutrients and fertilizing constituents in American feeding stuffs*

The total digestible nutrients given in the fifth column is the sum of the digestible crude protein, the digestible carbohydrates, and the digestible fat x 2.25.

*The asterisk after certain feeds indicates that the calculation of their digestible nutrients is based on available knowledge of other but similar feeds.

FEEDING STUFF	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
CONCENTRATES	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Corn and its products									
Dent corn	89.5	7.5	67.8	4.6	85.7	10.4	16.2	6.9	4.0
Flint corn	87.8	7.7	66.1	4.6	84.2	9.9	16.6	6.8	3.9
Sweet corn*	90.7	8.5	64.5	7.3	89.4	9.5	18.4	----	----
Corn cob	90.0	0.4	47.3	0.2	48.1	119.2	3.2	0.7	6.6
Corn-and-cob meal	89.6	6.1	63.7	3.7	78.1	11.8	13.8	5.8	6.3
Hominy feed, high grade	89.9	7.0	61.2	7.3	84.6	11.1	17.0	12.4	9.5
Gluten feed, high grade	91.3	21.6	51.9	3.2	80.7	2.7	40.6	6.2	2.3
Gluten meal, high grade	90.9	30.2	43.9	4.4	84.0	1.8	56.8	5.5	1.2
German oil, high grade	91.1	16.5	42.6	10.4	82.5	4.0	36.2	13.2	2.5
Corn bran	90.0	5.8	56.9	4.6	73.1	11.6	15.5	6.2	5.4
Wheat and its products									
Wheat, all analyses	89.8	9.2	67.5	1.5	80.1	7.7	19.8	8.6	5.3
Flour wheat, middlings	89.3	15.7	52.8	4.3	78.2	4.0	28.5	----	----
Standard wheat middlings (shorts)	89.6	13.4	46.2	4.3	69.3	4.2	27.7	21.1	11.8
Wheat bran, all analyses	89.9	12.5	41.6	3.0	60.9	3.9	25.6	29.5	16.2
Wheat feed (shorts and bran)	89.9	12.9	45.1	4.0	67.0	4.2	26.9	21.9	8.8
Wheat screenings	89.8	9.6	47.3	3.6	65.0	5.8	21.3	7.4	7.6
Rye and its products									
Rye	90.6	9.9	68.4	1.2	81.0	7.2	18.9	7.3	5.7
Rye middlings*	88.6	12.6	55.5	3.1	75.1	5.0	25.1	5.6	4.9
Rye bran	88.6	12.2	56.6	2.8	75.1	5.2	24.5	15.4	9.6
Rye feed (shorts and bran)	88.5	12.2	55.8	2.9	74.5	5.1	24.5	5.6	4.6
Oats and oat products									
Oats	90.8	9.7	52.1	3.8	70.4	6.3	19.8	8.1	5.6
Oat meal*	92.1	12.8	56.9	6.0	83.2	5.5	25.6	----	----
Oat hulls	93.2	2.0	45.2	1.3	50.1	24.1	6.4	2.1	5.8
Barley, products, and emmer									
Barley	90.7	9.0	66.8	1.6	79.4	7.8	18.4	8.5	7.4
Barley screenings*	88.6	8.3	47.7	2.5	61.6	6.4	18.4	----	----
Malt*	94.2	15.8	62.7	3.2	85.7	4.4	28.8	9.5	4.5
Malt sprouts	92.4	20.3	47.4	1.3	70.6	2.5	42.2	16.5	18.3
Brewers' grains, dried	92.5	21.5	30.5	6.1	65.7	2.1	42.4	9.9	0.9
Brewers' grains, wet*	24.1	4.6	8.7	1.5	16.7	2.6	9.1	2.4	0.3

TABLE II—*Continued*

FEEDING STUFF	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Rice and its products									
Rough rice	90.4	4.7	64.6	1.7	73.1	14.6	12.2	4.9	2.6
Rice polish	90.0	8.0	57.2	7.5	82.1	9.3	19.0	30.8	11.7
Rice bran, high grade	89.9	7.9	38.1	8.8	65.8	7.3	19.4	22.2	12.0
Rice hulls	90.7	0.3	12.3	0.7	14.2	46.3	5.3	0.9	2.2
Buckwheat and its products									
Buckwheat	87.9	8.1	49.7	2.5	63.4	6.8	17.3	10.0	7.0
Buckwheat middlings	88.0	24.6	38.3	6.1	76.6	2.1	45.3	23.4	11.8
Buckwheat bran, high grade	88.8	10.5	30.4	3.2	48.1	3.6	35.7	16.5	10.0
Buckwheat hulls*	89.7	0.4	13.9	0.7	15.9	38.8	7.0	5.7	8.6
The sorghums, etc.									
Kafir grain	88.2	9.0	65.8	2.3	80.0	7.9	17.8	5.7	3.1
Kafir-head chops	87.5	6.1	56.6	2.0	66.7	9.9	15.5	----	----
Kaoliang grain	90.1	8.5	67.0	3.3	82.9	8.8	16.8	----	----
Sorghum grain*	87.3	7.5	66.2	2.6	79.5	9.6	14.7	8.2	3.3
Broom-corn seed*	88.2	8.3	62.9	2.6	77.0	8.3	16.3	----	----
Barnyard millet seed*	89.8	7.6	57.0	3.4	72.2	8.5	17.1	----	----
Cottonseed and its products									
Cottonseed	90.6	13.3	29.6	16.5	80.0	5.0	31.2	15.0	15.0
Cottonseed meal, choice	92.5	37.0	21.8	8.6	78.2	1.1	70.6	26.7	18.1
Cottonseed meal, prime	92.2	33.4	24.3	7.9	75.5	1.3	63.7	26.6	18.0
Cottonseed meal, good*	92.1	31.6	25.6	7.8	74.8	1.4	60.2	26.6	18.0
Cold-pressed cottonseed cake	92.1	21.1	33.2	7.4	70.9	2.4	41.8	----	----
Cottonseed hulls	90.3	0.3	33.3	1.5	37.0	122.3	7.4	3.6	12.8
Cottonseed-hull bran*	91.6	0.2	33.3	0.9	35.5	176.5	5.4	----	----
Flaxseed and its products									
Linseed meal, old process	90.9	30.2	32.6	6.7	77.9	1.6	54.2	17.0	12.7
Linseed meal, new process	90.4	31.7	37.9	2.8	75.9	1.4	59.0	17.7	13.0
Legume seeds, their products									
Bean, navy, cull*	87.2	18.3	54.3	0.8	74.4	3.1	35.4	----	----
Cowpea	88.4	19.4	54.5	1.1	76.4	2.9	37.8	10.1	14.9
Horse bean	87.4	22.8	49.1	0.7	73.5	2.2	41.9	12.4	13.4
Pea, field	90.8	19.0	55.8	0.6	76.2	3.0	36.6	8.4	10.1
Peanut, with hull*	93.5	18.4	15.3	32.6	107.1	4.8	32.6	7.6	6.4
Peanut waste*	96.0	22.0	22.9	30.1	112.6	4.1	39.0	----	----
Peanut cake, from hulled nuts	89.3	42.8	20.4	7.2	79.4	0.9	76.2	11.6	10.0
Peanut cake, hulls included	94.4	20.2	16.0	10.0	58.7	1.9	45.4	----	----
Peanut hulls*	90.9	0.4	33.0	2.1	38.1	94.2	11.7	1.4	7.4
Soy bean	90.1	30.7	22.8	14.4	85.9	1.8	58.4	13.7	24.7
Soy bean meal, fat extracted	88.2	38.1	33.9	5.0	83.2	1.2	66.2	----	----
Velvet bean, seed and pod*	87.7	14.9	51.7	3.8	75.2	4.0	27.4	----	----
Oil-bearing seeds and their products									
Rapeseed cake	90.0	25.3	23.7	7.6	66.1	1.6	49.9	20.3	13.2

be compared, the differences between the soils are somewhat reduced. In round numbers there were removed in the crops of the first two years 37 grams of nitrogen from the Cookeville cylinders, 39 grams from the Crossville, 64 grams from the Gallatin, and only 36 grams from the Jackson cylinders. In the next three years there were removed from the same cylinders 40 grams of nitrogen from the Cookeville, 41 grams from the Crossville, 68 grams from the Gallatin, and 53 grams from the Jackson cylinders. The Jackson soil, therefore, ranked fourth in nitrogen production for the first two years, yielding only 56 per cent as much as the rich Gallatin soil and 95 per cent as much as the average of the Cookeville and Crossville soils, but ranked second in the succeeding three years, yielding 78 per cent as much as the Gallatin soil and 30 per cent more than the average of the Cookeville and Crossville soils. These results show the decidedly superior capacity of the Jackson soil to maintain the supply of available nitrogen.

RECOVERY OF NITROGEN FROM NITRATE OF SODA

Nitrate of soda furnishes nitrogen in a most available form for plants. The ready solubility of this salt leads to the conclusion that it would be more readily leached from one soil than another. On the other hand, the nitrate might be broken down and converted by microorganisms into organic forms, and so be retained longer in one soil than in another. In fact, there are several reasons for expecting that the availability would vary with different soils. Determinations of the percentage of nitrogen recovered by crops dressed with nitrate have been made at numerous places, but usually with only a single type of soil. At the New Jersey Station, however, considerable work of this kind has been done in comparative study of eight different soils.*

Five cropped cylinders in every series received annually, in early spring, a top-dressing of nitrate of soda, furnishing 1.1674 grams of nitrogen to each cylinder. All these nitrated cylinders had received annual applications of phosphate and potash, and the other treatments as indicated in Table V. Similarly treated cylinders, but unnitrated, are used for comparison and as a basis for the usual calculation of the nitrogen recovery. For example, the nitrogen removed in five years by the crops grown on the Cookeville cylinder, A8, which received ground limestone, acid phosphate, and muriate of potash, was 5.9994 grams. The crops from A10, which received ground limestone, acid phosphate, and muriate of potash in the same amount as A8, but was nitrated each year in addition, yielded 8.7653 grams of nitrogen. The difference between these two amounts, 2.7659 grams, is assumed to come from the nitrate, and is 47.38 per cent of the total nitrogen contained in the nitrate of soda applied. Table VIII gives the calcu-

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*N. J. Exp. Sta. Bul. 289, Cylinder Experiments Relative to the Utilization and Accumulation of Nitrogen, by Jacob G. Lipman and A. W. Blair. See also Report of the Soil Chemist and Bacteriologist of the N. J. Sta., by Jacob G. Lipman and Augustine W. Blair, for the year 1914.

TABLE VII—*Summary of nitrogen removed by crops in each of two periods*

SOIL	Nitrogen removed by crops in period 1909-1911	Nitrogen removed by crops in period 1911-1914, or after second manure and straw treatment	Gain (+) or loss (—) of nitrogen in three-year as compared with two-year period
1. All cropped cylinders—17 for each soil			
	Grams	Grams	Grams
Cookeville	53.7518	43.7168	—10.0350
Crossville	52.2290	43.3868	— 8.8422
Gallatin	100.8784	96.2351	— 4.6433
Jackson	58.8274	80.8399	+22.0125
2. The ten limed cylinders for each soil			
Cookeville	37.4945	40.3167	+ 2.8222
Crossville	38.7757	41.2112	+ 2.4355
Gallatin	64.0098	68.3251	+ 4.3153
Jackson	36.3485	53.0711	+16.7226

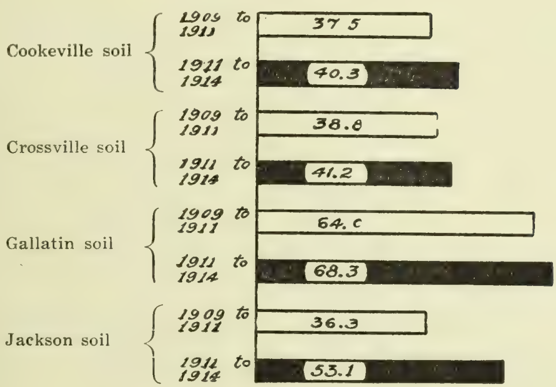


FIG. 4—GRAMS OF NITROGEN REMOVED BY CROPS FROM THE LIMED CYLINDERS IN EACH OF TWO PERIODS

From the data of the seventeen cylinders it may be seen that less nitrogen was removed by the crops in the last three years, or after the second application of manure and straw, than in the first two years for each of the three soils, Cookeville, Crossville, and Gallatin. In the case of the Jackson soil, however, there was an increase of nearly 37 per cent. If the limed, or ten highest-yielding, cylinders

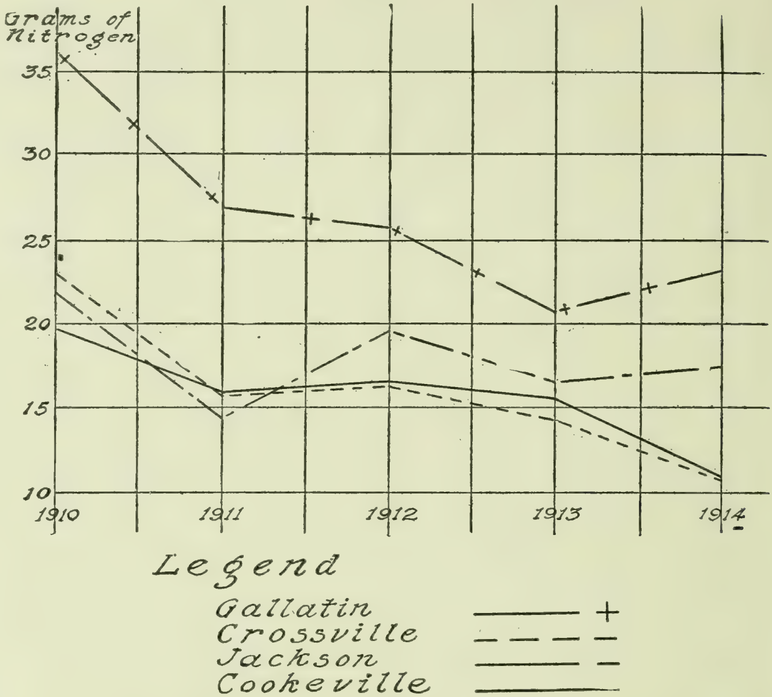


FIG. 3—NITROGEN FOUND IN CROPS FROM EACH OF THE FOUR SOIL TYPES —AVERAGE RESULTS FROM THE LIMED CYLINDERS ONLY

in the case of the Jackson soil, which was naturally slightly alkaline, were consistent yields obtained in all cylinders throughout the period. The Gallatin soil comes second, with fair regularity of yields for most cylinders. In the case of the Cookeville and Crossville cylinders, however, unbroken yields were obtained throughout the period only where the ground limestone was applied. In fact, without manurial treatment the fertility of these two soils was so low that scarcely appreciable crops were obtained on either soil after the second year.

Fig. 2 is a diagram of the crop yields from the limed cylinders of each soil type, and Fig. 3 shows the nitrogen found in the crops.

Table VII gives a summary of the nitrogen removed by the crops in each of two periods as determined by the first and second applications of manure and straw. In the first half of the table the total nitrogen removed by all of the seventeen cropped cylinders for each soil is shown, and this is followed by a similar statement for the ten best-producing cylinders, or those that were limed.

Fig. 4 is a diagram of the nitrogen found in the crops from the limed cylinders of each soil type for each of the two periods mentioned.

Since there is the possibility of a stimulating action on crop production at the outset, due to the aeration, etc., of the soils in handling, emphasis may be placed on the facts that the subsoils were placed in 1908, about a year and a half previous to the cropping here recorded, and that the surface soils used in 1908 and 1909 were replaced by fresh lots in the early fall of 1909. The first crop, oats, was planted in March, 1910. There was therefore an interval of about six months between the placing of the surface soils and the planting of the oats, during which there were heavy, leaching rains, which would be expected to carry away any abnormal accumulation of nitrates. Also neither the soils nor the subsoils were dried out at any time previous to placement beyond a moisture content of from 12 to 15 per cent, or such as is common in the field.

CROP RESULTS

YIELDS AND AMOUNTS OF NITROGEN REMOVED

Table VI (see Appendix) gives the yields of both air-dry substance and nitrogen obtained from each cylinder. This table shows that only

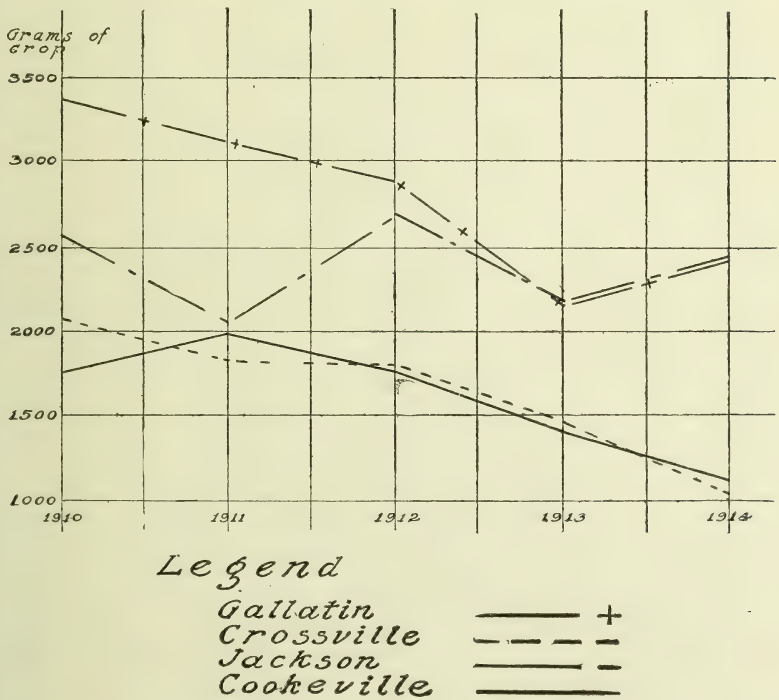


FIG. 2—CROP YIELDS OF EACH OF THE FOUR SOIL TYPES—AVERAGE YIELDS OF LIMED CYLINDERS ONLY

The uncropped cylinders were kept clean of weeds or bare throughout the five years, but received the same tillage as the cropped.

Table V—*List of experiments and manurial treatment of cylinders*

Exp. No.	Treatment	Cylinders to which applied	Cropping
1	L	A1, C1, E1, G1	Cropped
2	F	A2, C2, E2, G2	Cropped
3	LF	A3, C3, E3, G3	Cropped
4	O	A4, C4, E4, G4	Cropped
5	LFS	A5, C5, E5, G5	Cropped
6	LFSPK	A6, C6, E6, G6	Cropped
7	PK	A7, C7, E7, G7	Cropped
8	LPK	A8, C8, E8, G8	Cropped
9	PKN	A9, C9, E9, G9	Cropped
10	LPKN	A10, C10, E10, G10	Cropped
11	SPK	B1, D1, F1, H1	Cropped
12	LSPK	B2, D2, F2, H2	Cropped
13	SPKN	B3, D3, F3, H3	Cropped
14	LSPKN	B4, D4, F4, H4	Cropped
15	S	B5, D5, F5, H5	Cropped
16	LS	B6, D6, F6, H6	Cropped
17	LFSPKN	B7, D7, F7, H7	Cropped
18	LPK	B8, D8, F8, H8	Uncropped
19	LFPK	B9, D9, F9, H9	Uncropped
20	LSPK	B10, D10, F10, H10	Uncropped
21	LFSPK	J1, 4, 7, 10	Uncropped
22	LPKN	J2, 5, 8, and I9	Uncropped
23	LSPKN	J3, 6, 9, and I10	Uncropped
24	O	I1	Uncropped
25	L	I2	Uncropped
26	PK	I3	Uncropped
27	FSPK	I4	Uncropped
28	FS	I5	Uncropped
29	LFS	I6	Uncropped
30	FeFS	I8	Uncropped

OTHER CONDITIONS AFFECTING THE CROP YIELDS

Seventeen cylinders for each kind of soil were planted annually to the crops mentioned. No artificial watering was given, and the cylinders were fully exposed to the weather the year round. When practically matured, the crops were harvested, placed in paper bags, and thoroughly air-dried in the laboratory, so that the moisture content, as found by a number of determinations, was very nearly 10 per cent. The crops were then weighed, ground and analyzed for nitrogen.

TABLE IV—*Composition of nitrogenous materials and nitrogen furnished by each material in the five-year period*

MATERIAL	Nitrogen content (air-dry substance)	Nitrogen furnished per cylinder
	Per cent	Grams
Nitrate of soda	16.080	5.8370
Manure—		
(1) 1909	1.490	4.4700
(2) 1911	1.840	5.5200
Straw—		
(1) 1909	0.530	0.9616
(2) 1911	0.404	0.7330

SYMBOLS

For the sake of brevity the following symbols are used in Table V and others which follow:

L—An application of 181.44 grams of ground limestone per cylinder, equivalent to 2 tons per acre. This application was made only once, and at the outset of the experiments, to each cylinder where indicated.

F—An application of 300 grams of air-dried farmyard manure, practically free from straw and equivalent to about 12 tons of fresh manure per acre. This amount was applied in 1909 and again in 1911, after the removal of the fourth crop.

S—An application of 181.44 grams of chopped straw per cylinder, or at the rate of 2 tons per acre. This application was made at the outset and was repeated in 1911 as for the manure.

N—An annual application of 7.26 grams of nitrate of soda, or at the rate of about 160 pounds per acre.

PK—An annual application of 13.60 grams of acid phosphate and 4.54 grams of muriate of potash per cylinder, or 300 pounds and 100 pounds per acre, respectively.

THE CROPS GROWN

Two crops were harvested each year on the cropped cylinders, as follows:

1910—Oats, German millet
1911—Wheat, German millet
1912—Wheat, German millet
1913—Wheat, German millet
1914—Wheat, German millet

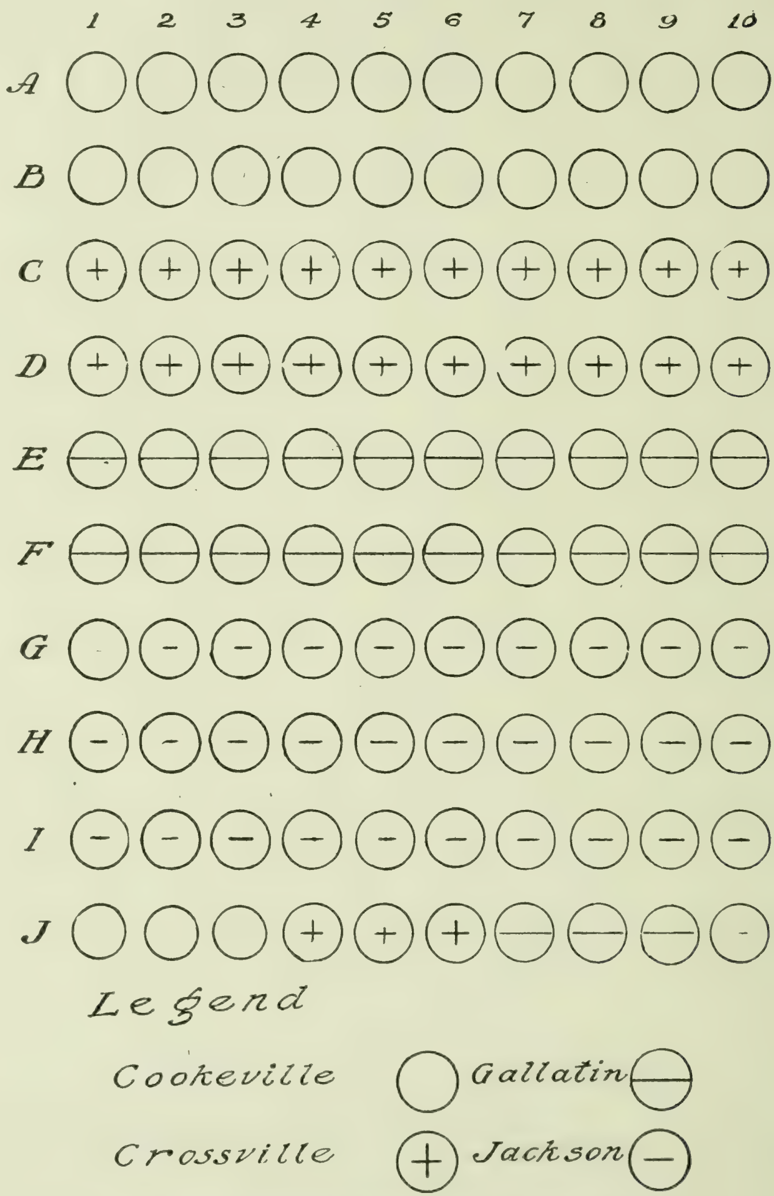


FIG. 1—ARRANGEMENT OF CYLINDERS IN FIELD

	Mean temperature	Rainfall
	Degrees F.	Inches
Spring	57	13.92
Summer	75	12.39
Fall	58	9.03
Winter	39	11.04

Lysimeter experiments at the Station farm, with cans 4 feet deep and 1/5,000 acre in surface area, from which both a crop of wheat and a crop of millet were harvested each year, gave the data of Table III for the two-year period, November 1, 1912, to November 1, 1914.

TABLE III—*Results of lysimeter experiments for two-year period Nov. 1, 1912, to Nov. 1, 1914*

SOIL	Liters of precipitation	Water leached through soil	
		Liters	Per cent
Cookeville	1685.8	726.9	43.12
Crossville	1685.8	857.4	50.86
Gallatin	1685.8	716.4	42.50

The data indicate the heavy leaching which cropped soils undergo.

MANURIAL TREATMENTS

Figure 1 shows the numbering and arrangement of the cylinders, and Table V gives the manurial treatment of each cylinder for the five years, 1909 to 1914, inclusive. The ground limestone contained no particles larger than 2 mm in diameter and analyzed 90.46 per cent of carbonates, less than one per cent of which was magnesium carbonate. The farmyard manure was freed from straw as far as practicable, thoroughly air-dried, ground to pass through a 2-mm sieve, and thoroughly mixed before being weighed out for the cylinders. Each application of 300 grams was mixed throughout the surface 5 inches of soil, about one inch of soil next to the subsoil being left as an absorbent layer. The straw was cut into pieces about one inch in length previous to application. The acid phosphate was of a standard make, analyzing about 16 per cent of available P_2O_5. Commercial muriate of potash, analyzing about 50 per cent K_2O, was used.

All the materials were carefully worked into the surface soil previous to a planting, except the nitrate of soda, which was applied as a surface dressing to the cereal crop in early spring, generally about the middle of March.

The composition of nitrogenous materials and the total amount of nitrogen furnished by each for the five-year period are given in Table IV.

during the cold months. The Crossville soil, on the other hand, is open and porous and heaves badly during the winter. The Gallatin soil, like the Crossville, heaves badly in the winter. It is darker-colored and "heavier" than the Crossville soil, and, like the latter, drains well. The Jackson soil rather closely resembles, in its physical properties, the Cookeville soil, but it drains less readily, especially when uncropped, due, evidently, to its very high content of silt.

TABLE II—*Mechanical analyses of the soils*

SOIL	Fine gravel 2-1 mm	Coarse sand 1-.5 mm	Medium sand .5-.25 mm	Fine sand .25-.1 mm	Very fine sand .1-.05 mm	Silt .05-.005 mm	Clay .005-0 mm
Cookeville	1.37	2.72	3.32	21.98	20.75	43.40	6.46
Crossville	0.75	2.24	2.85	19.02	16.57	46.38	12.19
Gallatin	1.54	2.03	1.32	2.79	9.92	65.59	16.81
Jackson	0.14	2.30	2.53	2.76	4.22	79.06	8.97

SIZE OF CYLINDERS, AMOUNTS OF SOIL USED, ETC.

The four soils described, together with their subsoils to a depth of 4 feet, were brought, in 1908, to the Experiment Station farm at Knoxville in sufficient quantity to fill 100 cylinders, each 4 feet deep and 2.225 feet in diameter. The exposed, or surface, area of soil in each cylinder was, therefore, 1/10,000 acre. Each lot of soil had been kept to itself and the corresponding subsoil had been removed in layers, as determined by color, so that they might be placed in the cylinders in the order in which they occurred in the field. The changes in color were sufficient to enable the line of demarcation between any two layers to be distinguished with little difficulty. The depth of the surface soil used for each type varied with the degree of compaction, but was in the neighborhood of from 5 to 6 inches. The weights of the water-free fine earth (particles not over .5 mm in diameter) of (1) the surface soil and (2) the first 6 inches of subsoil per cylinder were as follows:

	Soil	Subsoil
	Grams	Grams
Cookeville soil	52,753	75,000
Crossville soil	53,343	75,000
Gallatin soil	51,982	65,000
Jackson soil	50,757	73,000

CLIMATIC CONDITIONS

From September 1, 1909, to September 1, 1914, practically the five-year period of the experiments, the daily mean temperature and the average rainfall per season were, according to the U. S. Weather Bureau observations, as follows:

with limestone soils of this State. The Jackson soil is low in phosphoric acid and potash, but somewhat better supplied with calcium oxide than even the Gallatin soil. The content of nitrogen is very low, and distinctly lower than that of any of the other soils.

TABLE I—*The chemical composition of the soils—analyses made by the official method, HCl of 1.115 Sp. Gr. being used. Results on moisture-free basis*

CONSTITUENT	Soil			
	Cookeville	Crossville	Gallatin	Jackson
	Per cent	Per cent	Per cent	Per cent
Insoluble matter and soluble silica	93.150	89.260	84.340	92.460
Potash (K_2O)	0.077	0.138	0.420	0.150
Soda (Na_2O)	0.220	0.270	0.270	0.300
Lime (CaO)	0.093	0.051	0.275	0.330
Magnesia (MgO)	0.105	0.243	0.370	0.244
Manganese oxid (Mn_3O_4)	0.050	0.097	0.265	0.093
Ferric oxid (Fe_2O_3)	0.887	1.740	3.215	0.890
Alumina (Al_2O_3)	2.353	4.290	5.525	3.130
Phosphorus pentoxid (P_2O_5)	0.032	0.035	0.342	0.048
Sulphur trioxid (SO_3)	0.025	0.034	0.075	0.025
Carbon dioxid (CO_2)	0.028	0.046	0.085	0.058
Volatile matter	2.992	3.694	5.015	2.462
Total	100.012	99.898	100.197	100.190
Humus	0.880	0.730	1.520	0.500
Nitrogen (total)	0.0742	0.0784	0.1463	0.0593
Organic carbon	1.135	1.234	1.494	0.590
Acidity by Veitch method	0.099	0.182	0.205	Alkaline

As judged by the Veitch test the Cookeville, Crossville, and Gallatin soils were acid and the Jackson soil was slightly alkaline.

PHYSICAL CHARACTERISTICS OF THE SOILS

Mechanical analyses were made of the several soils by the method of the Bureau of Soils.* These analyses, as given in Table II, do not, however, give a good indication of the comparative textures of the soils. According to the analyses, there is considerable similarity between the Cookeville and Crossville soils. Marked differences, however, exist between them. The Cookeville soil puddles readily when wet, so that drainage is greatly retarded, and the soil heaves little

*Bu. Soils, U. S. Dept. Agr., Bul. No. 24.

The main object in undertaking the experiments discussed in this bulletin was to study what has been termed the "nitrogen economy" of the soil. The principal subjects considered are: (1) the comparative utilization of nitrogen by crops on different soils with regard to both the nitrogen naturally present and that supplied by nitrate of soda and farm manure; (2) the losses of both soil and subsoil nitrogen under various conditions, such as cropped and uncropped, limed and unlimed, manured and unmanured; and (3) indications of nitrogen assimilation from the atmosphere independent of legumes. In these experiments, therefore, only non-legumes were grown.

PRELIMINARY CONSIDERATIONS

DESCRIPTION OF SOIL TYPES USED IN THE EXPERIMENTS

As subjects for study, four types of soil were selected. These differ materially in character, but are representative of large areas in the State. Ample quantities were brought to the Station farm at Knoxville to fill 100 cylinders, as described later. These four types are as follows:

The Cookeville Soil. This is a poor, gray-colored sandy loam from the "Barrens" of the Highland Rim of Middle Tennessee.

The Crossville Soil. This is a poor loam of excellent physical make-up, such as is characteristic of the Cumberland Plateau, where it was obtained.

The Gallatin Soil. This is a fertile, brown-colored silt loam, a representative of the rich Central Basin section of Tennessee, but was taken from a field which was considered to be somewhat reduced in fertility.

The Jackson Soil. This is a gray-colored silt loam from West Tennessee, very high in silt, with poor drainage qualities, and considered to be troublesome to handle.

THE CHEMICAL COMPOSITION OF THE SOILS

Chemical analyses of the soils were made according to the methods of the American Association of Official Agricultural Chemists, hydrochloric acid of 1.115 Sp. Gr.* being used.

Judged by generally accepted standards, the Cookeville soil is poor in all the important elements of plant food. The Crossville soil has a considerably higher content of potash and a considerably lower content of calcium oxide than the Cookeville soil, but would be classed with the latter as poor in all the important elements of plant food. The Gallatin soil has a high content of phosporic acid and a good content of both potash and nitrogen. The calcium oxid supply is low when judged by common standards, but is good as compared

*Bu. Chem., U. S. Dept. Agr., Bul. No. 107 (Rev.), pp. 13-20.

A COMPARATIVE STUDY OF THE NITROGEN ECONOMY OF CERTAIN TENNESSEE SOILS

INTRODUCTION

The supply of nitrogen in the soil is more or less deficient throughout the State of Tennessee. This deficiency is most marked in the uplands which have been long under cultivation. If only virgin soils be considered a great variation is found, running from those which are rich in nitrogen, and which would remain highly productive for many years when cultivated, to those having only a scant natural supply, which would soon become exhausted so far as profitable crop production is concerned. The depletion of the nitrogen supply of the soil is greatly facilitated by the State's climatic conditions, which are favorable to both nitrification and loss by leaching throughout a large part of the year. In addition, the loss by erosion of cultivated land is severe. The best farmers make good use of the farmyard manure, and attach much importance to clover and other legumes, but according to the writer's observations they are unable, without feeding much cottonseed meal, or the like, to maintain more than a moderate state of fertility, even on naturally rich soils. For the poorer classes of soils the situation is serious, and the seriousness is increased by the fact that not only do crops remove from two to three times the amount of nitrogen as of the much-discussed phosphoric acid, but also that the cost per pound of readily available nitrogen is high—about four times that of phosphoric acid. The result is that under usual conditions very little commercial nitrogenous material can be used profitably for most of the common farm crops. Even in the case of high-priced market garden crops, only a small fraction of the nitrogen required to maintain an adequate soil supply can be profitably used.

As is well known, soil nitrogen can be not only lost in several ways, but also gained in several ways, in particular through bacteriological processes both with and without the intervention of legumes. Nitrogen is therefore prominent as the plant-food element and soil constituent which is most affected by all the conditions which arise in farm practice, such as kind and yield of crop, liming, manuring, soil drainage, tillage, and moisture supply.

There are also excellent reasons for thinking not only that different kinds of soil even under the same climatic conditions differ with regard to the availability of the nitrogen naturally present, but also that nitrogen applied in fertilizers and manures will be utilized better by the crops on one soil than on another.

The Agricultural Experiment Station

OF THE UNIVERSITY OF TENNESSEE

The Experiment Station building, containing the offices and laboratories, and the plant house, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy building, etc., are located one mile west of the University on the Kingston Pike. The fruit farm is adjacent to the Industrial School, and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

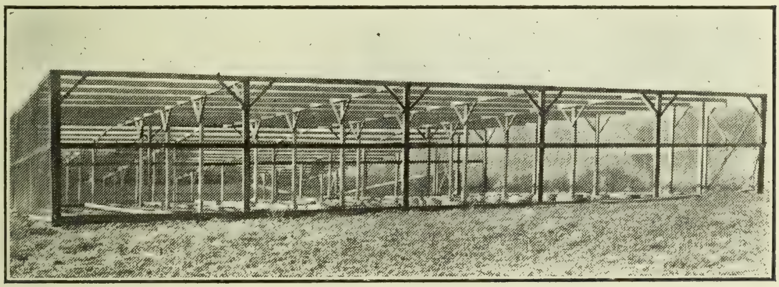
Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

Agricultural Experiment Station
OF THE
University of Tennessee

BULLETIN No. 118 APRIL, 1917

A COMPARATIVE STUDY OF THE NITROGEN ECONOMY OF CERTAIN TENNESSEE SOILS

By
C. A. MOOERS



THE PLANT
CYLINDERS IN SCREENED CAGE

KNOXVILLE, TENNESSEE

SPRAYING TO KILL WEEDS

In Lawns, Parks, Pastures and Hay and Grain Crops

The herbicides mentioned below can be used to destroy such weeds as mustard, dandelion, oxeye daisy, white-top, thistle, carrot, parsnip, elder, poison-ivy, ragweed, and all broad-leaved weeds. These sprays will leave narrow-leaved crops such as blue grass, timothy, red-top, and other grasses, including the growing cereal grains—wheat, oats, rye, etc., without injury if applied in proper strength and at the proper time.

The time of applying the sprays has to be adjusted to the condition of the crop and the relative development of the weeds. The first spraying should be made not later than the beginning of the bloom, and repeated applications should be made as new leaves are developed, provided the condition of the host crop will permit it. In grain fields, the best results with a single spraying will be obtained on most weeds by applying the spray just as the crop is ready to occupy the land.

Timothy and other grass meadows should be sprayed just before the grass begins heading out.

There are several solutions which may be used, but in general common salt and iron sulphate solutions are found most satisfactory. They are effective in killing the more common weeds and are not dangerous to stock in pastures in which they may be used.

HERBICIDES

34. Common Salt Solution

Common salt ....150 pounds
Water .... 50 gallons

Should be applied at the rate of 50 to 75 gallons per acre, sprayed. Useful for killing Canada thistle, dandelion, poison-ivy, yarrow, horse nettle, etc.

35. Iron Sulphate Solution

Iron sulphate (copperas) ....100 pounds
Water .... 50 gallons

Should be applied at the rate of 50 to 75 gallons per acre. Good to kill mustard, ragweed, white-top, yarrow, and other broad-leaved weeds in a field of growing grain or timothy.

be kept in a jar or bottle tightly corked. When ready for use dilute with water.

28. Copper Sulphate Solution

Copper sulphate (bluestone) .... 4 pounds
Water to make ....50 gallons

For use before the buds open, the above solution is fully as effectual as Bordeaux mixture, and is easier to prepare and apply. The weaker solution should be used upon the peach, although no injury would be done upon any kind of fruit tree, while in a dormant condition, if the stronger solution were used. *The stronger solution should not be applied to any plant after the buds have opened.*

29. Potassium Sulphide Solution (Liver of Sulphur)

Potassium sulphide ....1 ounce
Hot water ....2 to 3 gallons

Use as soon as it is cool.

30. Formalin Solution (For Oat and Wheat Smut)

Formalin (40% formaldehyde gas) ....1 pint
Water ....50 gallons

Soak the grain in this mixture for an hour and a half; spread out to become partly dry before sowing.

Grain may be piled upon a smooth floor and sprinkled with the solution, and shoveled over until the whole pile has been dampened. If this method be adopted, extreme care is necessary to insure the thorough dampening of every grain.

31. Formalin Solution (For Potato Scab)

Formalin ....16 ounces
Water ....30 gallons

Before cutting potatoes for planting, place them in a sack and soak them for two hours in the above mixture.

32. Corrosive Sublimate Solution (For Potato Scab)

Corrosive sublimate .... 2 ounces
Water ....15 gallons

Dissolve the corrosive sublimate in 2 gallons of hot water and dilute to make 15 gallons. Soak potatoes in solution for an hour and a half before cutting them.

33. Corrosive Sublimate Solution (For Cabbage Seed)

Corrosive sublimate .... 1 part
Water ....1000 parts

Soak seed in this solution for 15 minutes. Black rot may be introduced on cabbage seed. It is advisable to soak seed as directed under "32."

20. Nikoteen

Nikoteen .... 1/7 ounce
Water ....5 ounces

Place this upon a hot steam pipe and let it vaporize at night. The amount given above is sufficient for a space of 1,000 cubic feet.

21. Para-Dichlorobenzine

A new fumigant known as Para-dichlorobenzine does effective work in killing insects. Its action is slower than hydrocyanic acid gas, but it is very effective, and has the advantage of being neither inflammable nor poisonous to inhale.

22. Heat

To raise the temperature of a room or building to 120°F. and maintain this temperature from 8 to 24 hours, will kill insects of stored products, grain and flour, and also household insects.

FUNGICIDES

23. Self-Boiled Lime-Sulphur Solution

Stone lime (burnt lime) .... 8 pounds
Sulphur (flour) .... 8 pounds
Water ....50 gallons

24. Regular Bordeaux Mixture

Copper sulphate (bluestone) .... 5 pounds
Quicklime (burnt lime) .... 5 pounds
Water ....50 gallons

Dissolve the copper sulphate by suspending it in a bran bag or gunny sack in a wooden vessel containing 4 or 5 gallons of water. Slake good burnt lime in another vessel. When ready to use the Bordeaux mixture, add each of the above-mentioned solutions to two separate barrels, each diluted to make 25 gallons. These two solutions may now be added by pouring one into the other and thoroughly mixing. The result is 50 gallons of the Bordeaux mixture ready for use. This solution may be used on foliage not especially sensitive to copper.

25. Strong Bordeaux Mixture

Copper sulphate (bluestone) .... 6 pounds
Quicklime (burnt lime) .... 4 pounds
Water ....50 gallons

Separated, the sulphate and lime may be kept for some time, but when mixed the solution should be used at once.

26. Weak Bordeaux Mixture

Copper sulphate (bluestone) .... 2 pounds
Quicklime (burnt lime) .... 2½ pounds
Water ....50 gallons

Make according to directions under "24."

27. Ammoniacal Copper Carbonate Solution

Copper carbonate .... 6 ounces
Ammonia .... 3 pints
Water ....40 to 50 gallons

Dissolve the copper carbonate in the ammonia. The solution may

or

Sodium cyanide (96-98) ....1 ounce
Sulphuric acid ....1½ ounces
Water ....2 ounces
Stock to be fumigated 40 minutes.

16. Hydrocyanic Acid Gas (Weak)

For fumigating June-budded stock and for roses, buds, and scions, use the following charge:

Potassium cyanide (guaranteed 98 per cent pure) ⅔ ounce
Sulphuric acid (sp. g. 1.83) ....1½ ounces
Water ....3 ounces
Stock to be fumigated 40 minutes.

Caution.—Hydrocyanic acid gas is lighter than air, highly penetrating, and a *deadly poison.* The enclosure in which this gas is used should be perfectly air-tight. Care should be taken to get the right chemicals for this fumigating, the cyanide to be fused 98 per cent, the sulphuric acid to be the best commercial, specific gravity 1.83. For more detailed information upon fumigation, see Bulletin No. 2 of the Tennessee State Board of Entomology, on The Fumigation of Nursery Stock.

17. Carbon Bisulphide

For fumigating grain bins and other enclosures.

1½ tablespoonfuls to 100 lbs. grain.

5 lbs. to 100 bu. grain.

5 to 8 lbs. to 1000 cubic feet.

Leave in tightly closed bin for 24 hours. The bisulphide may be thrown upon the grain, or it may be put into shallow dishes and set upon the grain. The gas is much heavier than air and sinks down through the grain, killing any insects that may be there. The temperature should be 65 degrees or higher. A trade name for carbon bisulphide is "Fuma."

Caution—Carbon bisulphide is highly inflammable. The enclosure containing this gas should not be approached with a lighted lantern, match, pipe, or cigar. When fumigation is over the bin should be thoroughly ventilated.

18. Carbon Tetrachloride

2 pounds to each 100 cubic feet.

This fumigant is non-explosive and may be used in place of carbon bisulphide, where there is possible danger of fire. It is slower in its action than carbon bisulphide.

19. Sulphur

Burn 6 ounces of sulphur in a space of 1,000 cubic feet. Keep closed for at least 12 hours.

9. Tobacco Solution (Homemade)

Tobacco (waste of stems)	1 pound
Water	3 gallons

Steep in a covered vessel for 3 hours; strain, and use as a spray. For delicate foliage, this concentrated solution may be reduced with equal parts of water.

The soap-solution formula given below may be added.

10. Tobacco Solution (Factory-made)

There are today on the market several preparations of concentrated tobacco solutions. They are sold under various trade names, and contain 10, 20, 30, and 40 per cent of nicotine, by weight. They are very convenient to use. The amount of dilution is indicated upon the container.

11. Tobacco Dust

Tobacco dust, snuff, or warehouse sweeping can be used with partial success against the root aphis.

12. Soap Solution

Laundry soap	1 pound (2 bars)
Water	15 gallons

Dissolve the soap in hot water and apply when warm.

13. Starvation Method for Killing Cutworms

Late summer cultivation, followed by shallow cultivation throughout the fall, winter and early spring months, will in a large measure starve out the cutworm. All growths should be kept from the soil during the late summer, fall, winter, and early spring. The few worms that remain will be readily attracted by poison bait.

14. Bait for Cutworms

Bran or middlings	40 pounds
Paris green	1 to 2 pounds

Add enough molasses to sweeten well; mix with water to make a thick mash. Spread around on the ground late in the evening. Keep fowls from this.

FOR FUMIGATING

15. Hydrocyanic Acid Gas (Strong)

For fumigating apple and pear stock, plums and peaches, one year old, and for all other hardy deciduous trees, one year old or more; also for the control of household pests.

For each 100 cubic feet of space in the fumigating house or box, use potassium or sodium cyanide and sulphuric acid, as follows:

Potassium cyanide (guaranteed 98 per cent pure)	1 ounce
Sulphuric acid (sp. g. 1.83)	2 ounces
Water	4 ounces

Best results can be obtained by making a larger quantity, say four times this amount, as follows: To 8 or 10 gallons of water in a barrel add 32 pounds of fresh stone lime (the quicker-acting the better); when the slaking begins add 32 pounds of fine sulphur which has been run through a sieve to break up all lumps. As the lime continues to slake, water may be added to keep it from drying. The mixture should be constantly stirred until the slaking is over, when more water is added to stop the cooking. Strain and dilute to make 200 gallons of spray. Only a small amount of soluble sulphur should be present; the desired solution is a mechanical mixture of lime and sulphur. In straining the spray the coarse parts of the lime are to be taken out, but the sulphur worked through the sieve.

HOW AND WHEN TO USE THIS SPRAY

The self-boiled lime-sulphur solution should be applied in the form of a fine spray by a pump equipped with a good agitator. The time for applying will be governed by the disease to be treated. The number of applications may be one, two, three or four, according to conditions and the objects sought.

In place of the self-boiled lime-sulphur solution made at home, the commercial concentrated solution may be diluted for summer use. With peach this should be used experimentally. With apple the following reduction gives good results:

Hydrometer reading of the concentrated lime-sulphur solution Degrees Baume	Water to add to one gallon of the commercial concentrated lime-sulphur solution Gallons
35	45
34	43½
33	41¼
32	40
31	37½
30	36¼
29	34¼
28	32¾
27	31
26	29½
25	27¼

The lime-sulphur wash, from the standpoint of cheapness, accessibility, and efficiency, is the best spray known for the San Jose scale.

The time for applying the lime-sulphur wash is while the trees are dormant, as in the late fall, winter, or early spring. Prune the trees before spraying, and do thorough spraying. If all parts of the trees cannot be covered at the first spraying repeat the process soon.

6. Home-Boiled Lime-Sulphur Solution

Home-boiled lime-sulphur may be made after many different formulas. The one which we have used with best success is made from

Stone lime (burnt lime) ....21 pounds
Flour of sulphur ....18 pounds
Water ....50 gallons

Into the boiler, kettle, or tray (a barrel or tank if steam is to be used) place 5 or 6 gallons of water; to this add the sulphur, which has been passed through a flour sieve; then the lime, a small quantity at a time. Fire should now be started under the boiler. After all the lime has been added and the slaking is finished, add water to keep to a good boiling consistency, and boil vigorously from 40 to 60 minutes. The solution is now ready to be thinned and strained carefully into the spray tank or barrel; sufficient water being added to make 50 gallons of spray.

This spray is for winter, late fall, or early spring use. Never use while leaves or buds are opening. Never put this solution into a copper tank or sprayer, for its action upon copper is rapid and will soon ruin a receptacle of this metal.

This winter spray is for San Jose scale and leaf-curl.

7. Factory-Boiled Lime-Sulphur Solution

A very similar solution can be obtained in concentrated form from factories, and is then known as the factory-boiled lime-sulphur solution. This is usually diluted with from 7 to 9 parts of water to make the winter spray. There are many reliable grades which are as efficient as the home-boiled solution. If good lime cannot be obtained and the proper care given in making the mixture the factory-boiled solution should be used. The commercial product, at its present price, and of the quality now being furnished, is to be recommended.

8. Self-Boiled Lime-Sulphur Solution

The experiments with the self-boiled lime-sulphur solution for several years in different states have given results which highly commend this spray for the troubles which have heretofore been met with difficulty. Credit is due Mr. W. M. Scott, formerly Pathologist of the Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C., for his preliminary experiments in 1907 and 1908. The following formula, which has given best results, is from Bulletin 174 of that Bureau:

Flour of sulphur............................. 8 pounds
Fresh lime (burnt) .... 8 pounds
Water ....50 gallons

page 115 (A and B). About 1 inch from the lower end of the cylinder is a row of seven holes each ¼ inch in diameter. In the center of the bottom of the cylinder is a single opening ½ inch in diameter. The plunger consists of a ¼-inch iron rod with tin cone 3½ inches high and of a circumference that will permit it to fit nicely within the cylinder, as shown on page 115 (C). This is firmly soldered on one end of the rod and a handle is fitted on the other. A row of five holes, each ¼ inch in diameter, is made ½ inch from the base of the cone. In the base is an opening ½ inch in diameter. The openings at the base of the cone may be increased in number and lessened in diameter. This hastens the operation of emulsifying, but increases the labor. The above-described implement can be made by any tinsmith, and is inexpensive.

4. Treatment for Ticks, Horn Flies, Stable Flies, Etc.

Cottonseed oil (fish oil may be substituted)	1 gallon
Sulphur	1 pound
Carbonate of potash	1 pound
Concentrated lye	3 ounces
Beeswax	½ pound
Zenoleum	1 pint
Water	3 gallons

Heat the cottonseed oil, sulphur, potash, and beeswax until the beeswax is melted, then add 3 gallons of cottonseed oil or fish oil. To this add 1 pint of zenoleum or crude carbolic acid. Before applying this wash to cattle or horses, dilute with equal parts of water, thoroughly mixing it to form a good emulsion.

5. Whale Oil Soap Solution

Whale oil soap	¼ pound
Hot water	1 gallon

Use for summer spray.

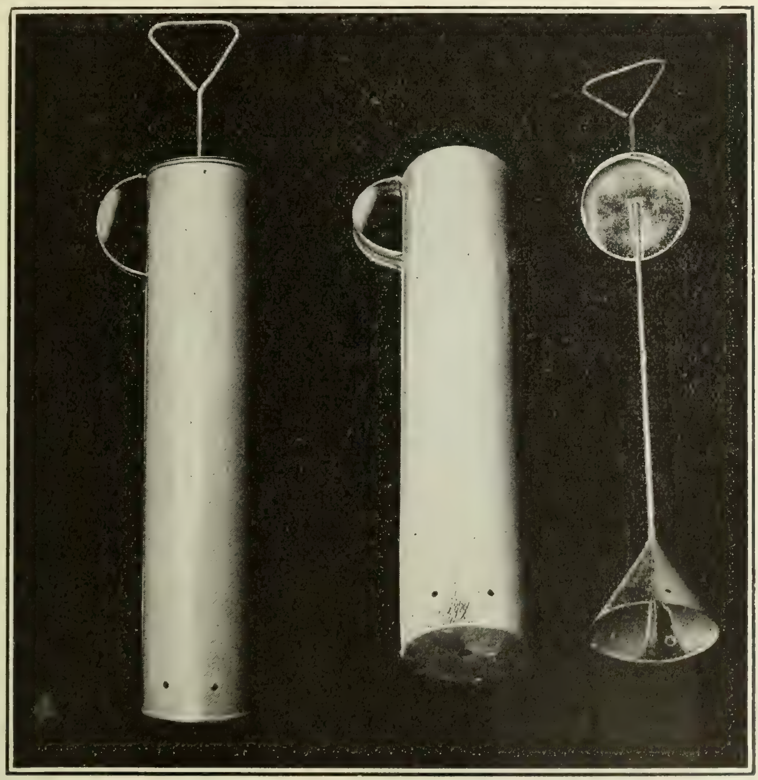
The Lime-Sulphur Solutions

The sprays made from lime and sulphur may be divided into three classes, viz., the home-boiled, factory-boiled and self-boiled. The first two act both as fungicides and insecticides; the last only as a fungicide. All the lime-sulphur solutions have efficiency and cheapness, which commend them highly.

How to make an oil emulsion

In the making of an emulsion it is essential that the oil when added to the water be thoroughly agitated in order that a thorough mixing of the ingredients may be obtained. This may be accomplished by turning the nozzle of the force pump into the mixture and forcing the solution through. The heat, however, is injurious to the valves of the pump. A jet of steam, if handy, could be used with good results. A simple device for making a perfect emulsion is one originated by Prof. H. A. Morgan, mentioned in Bulletin No. 48 (second series) of the Louisiana Agricultural Experiment Station, Baton Rouge, La.

It consists of a tin cylindrical vessel, 18 inches long and 4 inches in diameter, and a plunger, or piston, 22½ inches long, as shown on



A B C

AN EMULSIFIER

of insects is essential. To obtain this, one has only to notice carefully the damage being done or study the insect and observe whether its mouth is provided with jaws for biting (chewing) or a beak for sucking. Until a distinct familiarity with insect anatomy and general classification is procured it may be better to send specimens to the Experiment Station for identification and remedial suggestion. Specimens should be accompanied by pieces of plants upon which the insects feed, and if possible samples of the damage done.

INSECTICIDES FOR BITING INSECTS

(Potato beetle, flea beetle, codling moth, currant worm, etc.)

1. Arsenate of Lead (Liquid)

Powdered arsenate of lead..1 to 3 pounds or 1 tablespoonful
Water..............................50 gallons or 1 gallon

or

Paste arsenate of lead......2 to 6 pounds or 2 tablespoonfuls
Water.............................50 gallons or 1 gallon

2. Arsenate of Lead (Dust)

Powdered arsenate of lead..................... 1 pound
Flour, air-slaked lime, road dust or ashes........10 pounds

To make a spray dissolve the dry or paste form of arsenate of lead in a small quantity of water, then dilute to make the desired quantity.

INSECTICIDES FOR SUCKING INSECTS

(Plant lice, scale, squash bug, etc.)

3. Kerosene Emulsion

Kerosene (coal oil) ....2 gallons
Soap ....½ pound
Water (soft) .... 1 gallon

Dissolve the soap in water by boiling, remove from the fire, add kerosene, mix vigorously until all forms a creamy mass and emulsion. Dilute according to the per cent wanted.

For 10 per cent oil emulsion add 17 gallons of water
For 15 per cent oil emulsion add 10½ gallons of water
For 20 per cent oil emulsion add 7 gallons of water
For 25 per cent oil emulsion add 5 gallons of water
For 30 per cent oil emulsion add 4 gallons of water
For 40 per cent oil emulsion add 2 gallons of water
For 50 per cent oil emulsion add 1 gallon of water

This gas being a *deadly poison,* strict precautions against breathing it should be taken.

Bordeaux mixture should be applied several times; once before the buds break, once after the blooms fall, and again after a lapse of ten days or two weeks. A fourth application may be made a week later. With some fungous diseases Bordeaux may be profitably used every ten days or two weeks. If the lime-sulphur wash has been used the first application of the Bordeaux may be omitted.

Information about insects and insect pests and fungous diseases will be gladly furnished if specimens of insects and affected plants are sent to us. Place the specimens in a box, wrap neatly, and put your name and address on the package. In an accompanying letter tell us all you have noticed about the insect or disease—its first appearance, rapidity of increase, extent of destruction, etc.

Never put the strong lime-sulphur solution in a copper sprayer. The chemical action between the copper and the solution is rapid, and does great injury to the sprayer. For the lime-sulphur solution a galvanized iron or wooden receptacle should be used.

In spraying, great care should be taken to cover all parts of the tree, shrub or plant. If a heavy rain immediately follows your application of a spray, the work should be done over. Do not spray when the foliage is wet.

Before spraying, it is best to prune the trees in order to economize in the surface to be covered by the spray; also to rid the trees of their worst-affected limbs. Burn the wood removed. Prune out the scale-affected branches, the dead wood, and the undesirable water sprouts. In the peach, new wood should make up the major part of the tree. An ideal time to spray is a quiet, bright day when the air is dry and cool.

Study spray formulas, and the different makes of spray pumps and nozzles, that you may select the best for your conditions.

Insecticides and fungicides

Insecticides are agencies which kill insects. Fungicides are agencies which destroy fungous diseases. When insects and fungous diseases prevail upon the same plants insecticides and fungicides may be combined and the two results gained from one application. Variable results have been obtained from the use of insecticides and fungicides, due largely to climatic conditions and to the quality, age and preparation of the ingredients used and the combinations made. A knowledge of the pest being treated and the nature of the plant infested is important.

For remedial treatment, insects are divided, according to their manner of feeding, into biting and sucking groups. Hence, in the economic application of insecticides a knowledge of the mouth parts

worm), Hessian fly, and many other pests are more or less affected by crop rotation, and their control by this method should be carefully studied.

In sections affected with contagious diseases of live stock, pasture rotation is essential. In the control of stomach and intestinal worms in sheep, hogs and cattle, intelligent rotation covering definite periods, based upon longevity and life-histories of the pests, is now recognized as the most available and economical plan.

The fever cattle tick may be permanently eradicated by positive rotation. It has been found that if cattle and horses are removed from a pasture during the summer months, it becomes free from ticks. During the winter if infested cattle are run upon a cornfield or other cultivated field upon which no animals have been during the summer all the ticks will drop off, after which the animals may be placed upon the pasture that was freed of ticks during the previous summer. The Tennessee Experiment Station has prepared a bulletin upon the eradication of the tick by pasture rotation methods, which may be had on application.

Beneficial insects

While it may seem anomalous, probably the greatest factors in the control of insects are other insects and fungous diseases which are parasitic within or upon them. Such are truly friends of the producer, but they cannot be brought thoroughly under his control until insect life is better understood. Unable to identify these friends or to understand their operations, man too often treats them as enemies or minimizes their mission.

Birds

Birds should be recognized as factors in insect control. It is not uncommon to find large numbers of birds doing effective work in controlling insect outbreaks.

NOTES OF PRACTICAL INTEREST TO FARMERS AND FRUIT GROWERS ON THE SUBJECT OF SPRAYING

All chemicals used in spraying should be kept correctly labeled and out of reach of children.

Never spray when the trees are in bloom. Such practice will injure developing fruit and kill bees, which are necessary for fertilization. Spray before the buds open and just after the blooms fall. The strong lime-sulphur solution is most effective in February and March.

In all the formulas which require quicklime, the best stone lime, freshly burned, should be used. Air-slaked lime will not answer.

When hydrocyanic acid gas is used, fully fifteen minutes should be allowed for ventilating the enclosure after the fumigation is over.

SUGGESTIONS FOR THE CONTROL OF INJURIOUS INSECTS AND PLANT DISEASES

By G. M. Bentley

Many people believe that insects and fungi are controlled only by applications of chemical preparations, and give little attention to the prevention of attacks by cultivation, drainage, planting, and rotation, based upon a knowledge of the habits and life-histories of the pests. This impression has led the writer to give the suggestions below regarding preventive measures. This bulletin is a revision of Bulletin 106, which is out of print.

PREVENTIVES

In general

While much may be accomplished in the control of insects and fungous diseases by the use of insecticides and fungicides, more attention should be given to the prevention of the introduction of crop pests by judicious legislation, to the selection of resistant plants, to the elimination of weeds and worthless plants which harbor pests or act as intermediary hosts and are often of the same family as those under cultivation, to judicious rotation of crops, and to better drainage, cultivation and fertilization.

Cultural methods

Cultural methods of overcoming attack and injury by pests are based upon a knowledge of their habits and life-histories. Simple rotations, the use of trap plants, fall plowing, early planting, and many other average operations of the farm, if done with an intelligent knowledge of the habits and development of the pests to be controlled, will often of themselves prove efficient.

Rotation

The succession of the same or similar crops on the same land has proved disastrous in more ways than by the reduction of soil fertility. Its encouragement of the increase of insects and fungi has become notorious. The corn-root worm, boll worm (or corn-ear

The Agricultural Experiment Station

OF THE UNIVERSITY OF TENNESSEE

The Experiment Station building, containing the offices and laboratories, and the plant house, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farm, the barns, stables, dairy buildings, etc., are located one mile west of the University on the Kingston Pike. The fruit farm is adjacent to the Industrial School, and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

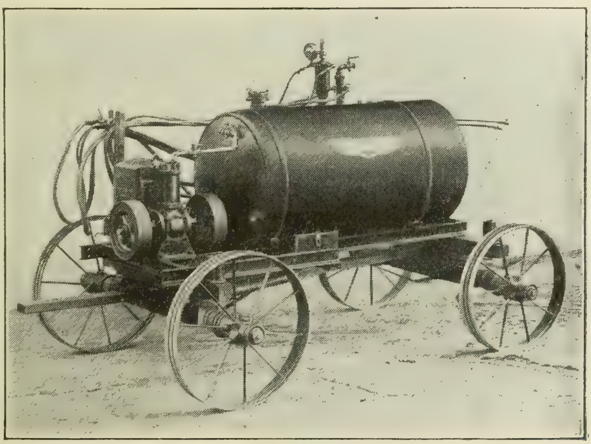
Agricultural Experiment Station
OF THE
University of Tennessee

BULLETIN NO. 117 MARCH, 1917

SUGGESTIONS FOR THE CONTROL OF INJURIOUS INSECTS AND PLANT DISEASES

BY

G. M. BENTLEY



AN EFFICIENT, INEXPENSIVE POWER SPRAYER

KNOXVILLE, TENNESSEE

On Other Farm Topics

Some of these publications will be of use to you in your work

Write to the Agricultural Experiment Station, University of Tennessee, Knoxville, for any of the following bulletins:

Regular Bulletins

X2. Pot culture of lettuce.
75. Selection for disease-resistant clover.
78. The soils of Tennessee.
81. Tick eradication.
83. Comparison and improvement of dairy herds in Tennessee.
84. Sheep and lambs in Tennessee.
86. Experiments with soils, fertilizers and farm crops.
87. The relation of the Weather Service to the farmers of Tennessee.
88. Insuring the peach crop.
90. Fertility experiments in a rotation of cowpeas and wheat. Part I.
91. Relation of temperature and rainfall to crop systems and production.
92. Experiments with fertilizers and field crops on important soil types of Middle Tennessee.
93. Tobacco insects of Tennessee. Tobacco culture in Montgomery County.
94. The cattle tick as affected by climate.
96. Fertility experiments in a rotation of cowpeas and wheat. Parts II and III.
97. Liming for Tennessee soils
101. The rational improvement of Cumberland Plateau soils.
102. The rational improvement of Highland Rim soils.
103. The influence of ammonium carbonate upon the determination of humus (Technical).
104. Feeding beef cattle.
105. The Tennessee wooden-hoop silo.
107. The non-existence of magnesium carbonate in humid soils.
108. Summer-pruning the peach.
109. Fertility and crop experiments at the West Tennessee Station.
110. A survey of sheep and lamb production in 1914.
112. The small grains in Tennessee.
113. North American fever tick.
114. Relation of steer feeding to farm economics.
115. Factors influencing the lime and magnesia requirements of soils (Technical).

Press Bulletins

20. Cattle tick extermination.
25. Cattle ticks frozen.
27. Rates and dates of seeding.
33. A select list of varieties of farm crops.
34. Lespedeza, or Japan clover.
38. "Cornstalk disease."
41. Sweet potato rots in Tennessee.
43. Bulletins available for distribution.

Write to the Division of Extension, College of Agriculture, University of Tennessee, Knoxville, for any of the following publications:

2. Kitchen Rules for the Home.
3. Cereals and Breads.
4. Eggs and Meats.
5. What to Do When Cleaning House.
7. Feeding Cottonseed Meal to Work Horses.
8. Suggestions for Farm Buttermaking.
9. Crimson Clover.
10. Rural Organization.
11. Farm Gardens.
12. How to Choose Woolens.
13. Directory of Tennessee Breeders of Registered Live Stock.
14. Good Light Bread.
15. Beef Cattle Profits.
16. Cheap Feed for Steers.
17. How to Feed Cottonseed Meal to Hogs.
18. Use the Winter Growing Season by Planting Legumes.
20. Getting a Stand of Alfalfa in Tennessee and Maintaining It.
21. Legumes and Truck Crops.
22. What to Do to Keep Well.
23. Use Meat in Many Ways.

If there is any other subject upon which you would like to have information, a letter addressed to the Agricultural Experiment Station or to the Division of Extension, University of Tennessee, Knoxville, will be answered promptly by the man or the woman who knows about the subject in which you are interested.

INDEX

TABLE VII—*Feeding rations recommended**

For Beef and Dairy Cattle

Ration No. 1

Lbs.	
35	Silage
2	Cotton-seed meal
7	Ground ear corn, or 6 lbs. barley
10	Cowpea hay, or alfalfa, or soy-bean hay

Ration No. 2

Lbs.	
40	Silage
10	Oat and vetch hay, or wheat and vetch hay
5	Cotton-seed meal

Ration No. 3

Lbs.	
30	Silage
3	Cotton-seed meal
6	Ground ear corn, or 5 lbs. barley
7½	Red-top hay
7½	Cowpea hay

Ration No. 4

Lbs.	
35	Silage
15	Cowpea hay, or alfalfa, or soy-bean hay
8	Ground ear corn, or 7 lbs. barley

Ration No. 5

Lbs.	
16	Cotton-seed hulls
5	Cotton-seed meal
8	Ground ear corn, or 7 lbs. barley

Ration No. 6

Lbs.	
30	Silage
5	Soy-bean meal, or cotton-seed meal
6	Ground ear corn, or 5 lbs. barley
10	Corn stover, or soy-bean straw

Ration No. 7

Lbs.	
30	Silage
10	Soy-bean straw, or corn stover
4	Cotton-seed meal
3	Dried brewers' grains

Ration No. 8

Lbs.	
15	Soy-bean straw, or corn stover
4	Cotton-seed meal
3	Dried brewers' grains

Ration No. 9

Lbs.	
20	Clover hay
8	Ground ear corn
2	Cotton-seed meal

For Beef Cattle—90 to 100 Days' Feeding Period

Ration No. 1

Lbs.	
50	Silage, entire period
3	Cotton-seed meal, 1st 30 days
4	Cotton-seed meal, 2nd 30 days
5	Cotton-seed meal, balance of period

Ration No. 2

Lbs.	
40	Silage, entire period
5	Cotton-seed meal, 45 or 50 days
6	Cottonseed meal, balance of period

Ration No. 3

Lbs.	
35	Silage, entire period
6	Cotton-seed hulls, entire period
4	Cotton-seed meal, 1st 30 days
5	Cotton-seed meal, 2nd 30 days
6	Cotton-seed meal, balance of period

Ration No. 4

Lbs.	
25	Cotton-seed hulls, entire period
5	Cotton-seed meal, 1st 30 days
6	Cotton-seed meal, 2nd 30 days
7	Cotton-seed meal, balance of period

For Horses and Mules

Ration No. 1

Lbs.	
4	Oats
2	Cotton-seed meal
10	Ground ear corn
12	Mixed hay

Ration No. 2

Lbs.	
2	Cotton-seed meal
4	Wheat bran, or middlings
12	Oat hay

Ration No. 3

Lbs.	
6	Corn
6	Wheat bran, or middlings
2	Cotton-seed meal
12	Timothy, or red-top hay

Ration No. 4

Lbs.	
10	Oats
2	Cotton-seed meal
6	Alfalfa, cowpea, or soy-bean hay
8	Timothy, or red-top hay

Ration No. 5

Lbs.	
8	Corn
4	Oats
12	Japan clover, alfalfa, cowpea, or soy-bean hay

Ration No. 6

Lbs.	
12	Corn
1.5	Cotton-seed meal
12	Japan clover, alfalfa, cowpea or soy-bean hay

*Tenn. State Dept. Agr., Bul. 2.

Table VI—*Weights and measures of feeding stuffs*

FEEDING STUFF	One quart weighs	One pound measures
Protein feeds	**Lbs.**	**Qts.**
Cottonseed meal	1.5	0.7
N. P. linseed meal	0.9	1.1
O. P. linseed meal	1.1	0.9
Gluten meal	1.7	0.6
Gluten feed	1.3	0.8
Germ oil meal	1.4	0.7
Distillers' dried grains	0.5-0.7	2.0-1.4
Malt sprouts	0.6	1.7
Brewers' dried grains	0.6	1.7
Wheat middlings (flour)	1.2	0.8
Wheat middlings (standard)	0.8	1.3
Wheat mixed feed	0.6	1.7
Wheat bran	0.5	2.0
H-O dairy feed	0.7	1.4
Oat middlings	1.5	0.7
Rye feed	1.3	0.8
Starchy feeds		
Whole oats	1.0	1.0
Ground oats	0.7	1.4
Whole wheat	1.9	0.5
Ground wheat	1.7	0.6
Whole barley	1.5	0.7
Barley meal	1.1	0.9
Whole rye	1.7	0.6
Rye meal	1.5	0.7
Whole corn	1.7	0.6
Corn meal	1.5	0.7
Corn-and-cob meal	1.4	0.7
Corn bran	0.5	2.0
Hominy meal	1.1	0.9
Corn and oat feed (Victor)	0.7	1.4
Quaker dairy feed	1.0	1.0
Oat feed	0.8	1.3

*Mass. Exp. Sta. Bul. 112.

TABLE IV—*Manurial value of farm products*

FEED	Amount fertilizing materials per ton*			Value fertilizing materials per ton†			Total value per ton
	Nitrogen	Phosphoric acid	Potash	Nitrogen	Phosphoric acid	Potash	
	Lbs.	Lbs.	Lbs.				
Meadow hay	20.4	8.2	26.4	$4.08	$ .41	$1.32	$5.81
Clover hay	40.1	11.2	36.6	8.03	.56	1.83	10.42
Alfalfa hay	52.2	12.2	35.8	10.44	.61	1.79	12.84
Soy bean hay	47.6	8.0	26.4	9.52	.40	1.32	11.24
Cowpea hay	28.6	10.4	29.4	5.72	.52	1.47	7.71
Wheat bran	49.2	54.6	28.6	9.83	2.73	1.43	13.99
Cottonseed meal	135.7	56.2	29.2	27.00	2.81	1.46	31.27
Wheat	37.5	15.8	10.6	7.50	.79	.53	8.82
Oats	36.4	12.4	8.8	7.28	.62	.44	8.34
Barley	39.7	15.4	9.0	7.93	.77	.45	9.15
Milk	10.2	3.4	3.0	2.04	.17	.15	2.36
Cheese	90.6	23.0	5.0	18.12	1.15	.25	19.52
Butter	5.7	.7	1.2	1.14	.03	.06	1.23
Live cattle	53.2	37.2	3.4	10.64	1.86	.17	12.67

*Data from Henry's "Feeds and Feeding."

†Based on the following prices: Nitrogen 20c, phosphoric acid 5c, and potash 5c.

TABLE V—*Fertility in farm produce removed annually per acre**

CROP YIELD PER ACRE	Market value	Fertilizing materials removed			Total retail value of fertility removed per acre	Manurial value of $10 worth†
		Nitrogen	Phos-ph'ric acid	Potash		
		Lbs.	Lbs.	Lbs.		
70 bu. corn	$ .70 per bu.	70	12	13	$15.25	$3.06
60 bu. oats	.45 per bu.	40	7	10	8.85	3.23
25 bu. wheat	1.00 per bu.	36	6	7	7.85	3.84
25 bu. soy beans	2.00 per bu.	80	13	24	17.85	3.57
1000 lbs. cottonseed	.25 per bu.	63	11	19	14.10	9.65
2 tons timothy hay	18.00 per ton	48	6	47	12.25	3.40
2 tons clover hay	15.00 per ton	80	10	60	19.50	6.49
4 tons alfalfa hay	20.00 per ton	200	18	96	45.65	5.70
2 tons cowpea hay	15.00 per ton	87	9	65	21.10	7.03
200 bu. potatoes	.50 per bu.	42	9	60	11.85	1.19

*Composition based upon data from Hopkins' "Soil Fertility and Permanent Agriculture," p. 154.

†Based on same prices as in Table IV.

ANIMAL	Per day per 1000 lbs. live weight: Dry matter	Digestible crude protein	Total digestible nutrients	Nutritive ratio
	Lbs.	Lbs.	Lbs.	1:
3 Fattening 2-yr-old steers on full feed				
First 50-60 days	22.0-25.0	2.0-2.3	18.0-20.0	7.0-7.8
Second 50-60 days	21.0-24.0	1.9-2.3	17.0-19.5	7.0-7.8
Third 50-60 days	18.0-22.0	1.8-2.1	16.0-18.5	7.0-7.8
4. Ox at rest in stall	13.0-21.0	0.6-0.8	8.4-10.4	10.0-16.0
5. Wintering beef cows in calf	14.0-25.0	0.7-0.9	9.0-12.0	10.0-15.0
6. Horses				
Idle	13.0-8.0	0.8-1.0	7.0-9.0	8.0-9.0
At light work	15.0-22.0	1.1-1.4	10.0-13.1	8.0-8.5
At medium work	16.0-24.0	1.4-1.7	12.8-15.6	7.8-8.3
At heavy work	18.0-26.0	2.0-2.2	15.9-19.5	7.0-8.0
7. Brood mares suckling foals, but not at work	15.0-22.0	1.2-1.5	9.0-12.0	6.5-7.5
8. Growing colts, over 6 months	18.0-22.0	1.6-1.8	11.0-13.0	6.0-7.0
9. Fattening lambs				
Weight 50-70 lbs.	27.0-30.0	3.1-3.3	19.0-22.0	5.0-6.0
Weight 70-90 lbs.	28.0-31.0	2.5-2.8	20.0-23.0	6.7-7.2
Weight 90-110 lbs.	27.0-31.0	2.3-2.5	19.0-23.0	7.0-8.0
10. Sheep, maintaining mature				
Coarse wool	18.0-23.0	1.1-1.3	11.0-13.0	8.0-9.1
Fine wool	20.0-26.0	1.4-1.6	12.0-14.0	7.5-8.5
11. Breeding ewes, with lambs	23.0-27.0	2.6-2.9	18.0-20.0	5.6-6.5
12. Growing, fattening pigs				
Weight 30-50 lbs.	46.2-51.0	7.8-8.5	41.0-45.4	4.0-4.5
Weight 50-100 lbs.	37.0-40.8	5.5-6.0	32.9-36.4	5.0-5.6
Weight 100-150 lbs.	32.4-35.8	4.4-4.9	28.8-31.9	5.5-6.2
Weight 150-200 lbs.	29.0-32.0	3.5-3.9	25.8-28.5	6.2-7.0
Weight 200-250 lbs.	25.5-28.1	3.0-3.4	22.7-25.0	6.5-7.3
Weight 250-300 lbs.	24.4-24.8	2.6-2.9	20.0-22.0	6.7-7.5
13. Brood sows, with pigs	20.0-24.0	2.4-2.7	18.0-21.0	6.0-7.0

	Digestible nutrients per day for each 100 lbs. live wt.: Total dry matter	Ash	Protein	Carbo-hydrates	Fat	Nutri-tive ratio
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:
14. Poultry. Hens in full laying*	5.50	.30	1.00	3.75	.35	1.46

*Jordan's Feeding of Farm Animals.

TABLE III—*Modified Wolff-Lehmann feeding standards for farm animals*

	Digestible crude protein	Total digestible nutrients
	Lbs.	Lbs.
1. Dairy cows		
For maintenance of 1000-lb. cow	0.700	7.925
To allowance for maintenance add:		
For each lb. of 3.5 per ct. milk	0.049-0.061	0.316
For each lb. of 4.0 per ct. milk	0.054-0.065	0.346
For each lb. of 4.5 per ct. milk	0.057-0.069	0.376
For each lb. of 5.0 per ct. milk	0.060-0.073	0.402
For each lb. of 5.5 per ct. milk	0.064-0.077	0.428

The amount of dry matter to be fed daily per 1,000 lbs. live weight to dairy cows may range from 15.0 lbs. or even less with dry cows to 30.0 lbs. with cows yielding 2.0 lbs. of butter fat per head daily. Cows producing 1.0 lb. of fat per head daily should receive about 21.0 to 25.0 lbs. of dry matter daily per 1,000 lbs. live weight. The nutritive ratio may readily be found by computation; for example, a 1,200-lb. cow yielding daily 30.0 lbs. of 3.5 per ct. milk will require for maintenance and production 2.31 to 2.67 lbs. digestible crude protein and 18.99 lbs. total digestible nutrients. The nutritive ratio should hence not be wider than 1:6.1 to 1:7.2.

LIVE WEIGHT	Actual, per head daily			Per 1000 lbs. live weight			Nutritive ratio
	Dry matter	Digestible crude protein	Total digestible nutrients	Dry matter	Digestible crude protein	Total digestible nutrients	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:
2. Growing, fattening steers							
100 lbs.	1.41	0.32	1.66	14.1	3.2	16.6	4.2
200 lbs.	4.81	0.67	3.48	24.0	3.4	17.4	4.1
300 lbs.	8.00	0.80	5.36	26.7	2.7	17.9	5.6
400 lbs.	9.72	0.87	6.32	24.3	2.2	15.8	6.2
500 lbs.	11.95	1.04	7.88	23.9	2.1	15.8	6.5
600 lbs.	13.94	1.22	9.25	23.2	2.0	15.4	6.7
800 lbs.	17.13	1.61	11.43	21.4	2.0	14.3	6.2
1000 lbs.	19.66	1.80	13.51	19.7	1.8	13.5	6.5
1200 lbs.	20.76	1.84	14.71	17.3	1.5	12.3	7.2

TABLE II—*Continued*

FEEDING STUFF	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Velvet bean*	17.9	2.7	7.2	0.4	10.8	3.0	5.6	1.3	4.5
Vetch, hairy	18.1	3.5	8.1	0.4	12.5	2.6	6.7	1.4	5.1
Mixed legumes and grasses									
Clover and mixed grasses*	27.3	2.2	14.1	0.6	17.7	7.0	4.8	----	----
Cowpeas and oats*	21.8	3.3	9.1	0.6	13.8	3.2	7.2	----	----
Cowpeas and sorghums*	18.7	0.7	10.0	0.3	11.4	15.3	2.4	----	----
Soy beans and corn*	23.8	1.7	13.6	0.6	16.7	8.8	4.3	1.1	4.0
Vetch and wheat	22.7	2.4	12.2	0.3	15.3	5.4	5.3	----	----
Roots and tubers									
Artichokes*	20.5	1.0	14.6	0.1	15.8	14.8	3.2	1.4	4.9
Beet, sugar	16.4	1.2	12.6	0.1	14.0	10.7	2.6	0.8	3.2
Carrot	11.7	0.9	8.6	0.2	9.9	10.0	1.9	1.1	2.7
Chufa*	20.5	0.4	10.2	3.3	18.0	44.0	1.1	----	----
Mangel	9.4	0.8	6.4	0.1	7.4	8.2	2.2	0.4	2.2
Potato	21.2	1.1	15.8	0.1	17.1	14.5	3.5	1.2	5.3
Sweet potato*	31.2	0.9	24.2	0.3	25.8	27.7	2.9	0.9	5.1
Turnip	9.5	1.0	6.0	0.2	7.4	6.4	2.2	1.3	2.9
Miscellaneous green forages									
Apple*	18.2	0.4	15.6	0.2	16.4	40.0	0.8	0.3	1.6
Apple pomace*	23.3	1.2	15.6	0.8	18.6	14.5	2.6	0.6	1.5
Cabbage	8.9	1.9	5.6	0.2	7.9	3.2	3.5	0.7	2.9
Cactus, prickly pear	16.5	0.4	8.9	0.2	9.7	23.2	1.3	0.7	4.3
Pumpkin, field	8.3	1.1	4.5	0.5	6.7	5.1	2.2	0.9	3.2
Rape	16.7	2.6	10.0	0.3	13.3	4.1	4.6	1.1	3.9
Sugar beet leaves*	11.6	1.2	6.3	0.1	7.7	5.4	3.0	1.2	5.5
Turnip tops*	15.0	1.8	7.3	0.1	9.3	4.2	4.5	1.5	5.2
SILAGE									
From corn, the sorghums, etc.									
Corn, well matured, recent analyses	26.3	1.1	15.0	0.7	17.7	15.1	3.4	1.6	4.4
Corn, immature	21.0	1.0	11.4	0.4	13.3	12.3	3.0	1.2	3.5
Corn, from frosted corn*	25.3	1.2	13.7	0.6	16.3	12.6	3.5	1.5	4.3
Corn, from field-cured stover*	19.6	0.5	9.9	0.4	11.3	21.6	2.2	----	----
Kafir	30.8	0.8	15.3	0.6	17.5	20.9	2.9	----	----
Sorghum	22.8	0.6	11.6	0.5	13.3	21.2	2.4	1.5	1.9
Miscellaneous silage									
Alfalfa*	24.6	1.2	7.8	0.6	10.4	7.7	5.6	----	----
Apple pomace*	20.6	0.9	15.0	0.6	17.3	18.2	2.6	0.8	2.2
Clover	27.8	1.3	9.5	0.5	11.9	8.2	5.9	----	----
Corn and soy bean	24.7	1.6	13.8	0.8	17.2	9.8	4.0	1.6	4.5
Cowpea	22.0	1.8	10.1	0.6	13.3	6.4	5.1	1.8	3.8
Pea-cannery refuse*	23.2	1.6	11.6	0.8	15.0	8.4	4.5	----	----
Sorghum and cowpea*	32.3	0.9	16.6	0.6	18.9	20.0	3.8	----	----
Wet brewers' grains*	29.8	5.2	11.1	1.9	20.6	3.0	10.2	----	----

TABLE II—*Continued*

FEEDING STUFF	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1 :	Lbs.	Lbs.	Lbs.
Fresh green grass									
Bermuda grass*	33.2	1.4	17.0	0.5	19.5	12.9	4.8	1.5	7.4
Bluegrass, Kentucky, all analyses	31.6	2.3	14.8	0.6	18.5	7.0	6.6	1.9	7.1
Brome grass, smooth*	33.0	2.9	15.0	0.2	18.3	5.3	6.7	2.0	8.6
Chess, or cheat*	39.6	1.5	20.8	0.6	23.7	14.8	5.1	2.9	10.8
Crab grass*	30.9	1.3	14.2	0.5	16.6	11.8	4.3	2.2	10.8
Fescue, meadow*	30.5	1.6	15.0	0.5	17.7	10.1	4.8	1.8	7.0
Johnson grass*	29.1	1.2	14.7	0.5	17.0	13.2	4.0	----	----
Meadow foxtail*	29.6	2.1	13.9	0.6	17.4	7.3	5.8	----	----
Millet, pearl, or cat-tail*	18.7	1.1	10.4	0.2	11.9	9.8	2.9	1.9	10.3
Mixed grasses, immature	29.7	3.6	14.5	0.9	20.1	4.6	8.2	2.1	7.9
Mixed grasses, at haying stage	30.8	1.7	15.2	0.6	18.3	9.8	4.8	2.5	6.4
Oat grass, tall, or meadow oat grass*	30.3	1.1	13.3	0.4	15.3	12.9	4.2	1.8	8.4
Orchard grass	29.2	1.7	13.0	0.6	16.1	8.5	4.6	2.1	9.5
Quack grass*	30.6	2.2	11.3	0.7	15.1	5.9	6.1	----	----
Red top	39.3	1.9	20.0	0.6	23.3	11.3	5.0	2.3	8.4
Rowen, mixed	28.2	3.3	14.0	0.9	19.3	4.8	7.5	2.0	7.5
Rye grass, perennial*	26.6	1.7	12.5	0.7	15.8	8.3	4.8	2.2	9.2
Sedges, western*	38.5	2.4	20.3	0.5	23.8	8.9	6.1	----	----
Sweet vernal grass*	31.2	1.5	16.1	0.5	18.7	11.5	4.2	2.0	6.4
Timothy, all analyses	37.5	1.5	19.3	0.6	22.2	13.8	5.0	1.8	6.7
Green fodder from the smaller cereals									
Barley fodder	23.2	2.3	11.5	0.4	14.7	5.4	5.3	1.3	6.8
Oat fodder	26.1	2.3	11.8	0.8	15.9	5.9	5.1	1.8	7.7
Rye fodder	21.3	2.1	12.2	0.5	15.4	6.3	4.2	1.5	4.9
Wheat fodder, all analyses*	27.4	2.8	15.1	0.6	19.3	5.9	5.8	1.9	7.2
Green legumes									
Alfalfa, all analyses	25.3	3.3	10.4	0.4	14.6	3.4	7.2	1.5	6.7
Clover, alsike*	24.3	2.7	11.8	0.4	15.4	4.7	6.6	1.8	9.2
Clover, bur*	20.8	3.4	8.2	1.1	14.1	3.1	8.2	----	----
Clover, crimson	17.4	2.3	8.1	0.4	11.3	3.9	4.8	2.0	4.1
Clover, mammoth, red*	25.1	2.7	12.4	0.3	15.8	4.9	6.4	----	----
Clover, red, all analyses	26.2	2.7	13.0	0.6	17.1	5.3	6.6	1.3	5.6
Clover, red, rowen	34.4	3.3	15.4	0.8	20.5	5.2	8.5	2.0	9.5
Clover, sweet*	24.4	3.3	10.3	0.3	14.3	3.3	7.0	1.3	5.0
Clover, white*	21.8	3.1	9.6	0.5	13.8	3.5	7.4	1.8	8.1
Cowpeas	16.3	2.3	8.0	0.3	11.0	3.8	4.8	1.4	6.2
Kudzu vine*	30.6	4.2	13.9	0.5	19.2	3.6	8.8	----	----
Lespedeza, or Japan clover*	36.6	4.5	17.1	0.6	23.0	4.1	10.7	----	----
Peas, field, Canada	16.6	2.9	7.1	0.3	10.7	2.7	5.8	1.1	2.8
Soy beans, all analyses	23.6	3.2	10.2	0.5	14.5	3.5	6.6	1.8	5.7

TABLE II—*Continued*

FEEDING STUFF	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Clover, white	91.9	11.8	43.3	1.5	58.5	4.0	25.9	5.2	20.0
Clover meal*	91.5	8.1	42.0	1.3	53.0	5.5	21.9	4.0	17.2
Clover rowen	85.2	10.7	33.1	2.2	48.8	3.6	26.4	----	----
Cowpea, all analyses	90.3	13.1	33.7	1.0	49.0	2.7	30.9	9.6	41.3
Kudzu vine*	92.9	11.4	39.8	1.2	53.9	3.7	26.7	----	----
Lespedeza, or Japan clover*	88.2	8.6	41.1	1.1	52.2	5.1	19.4	10.3	20.7
Pea, field, Canada	88.9	12.2	40.1	1.5	56.6	3.6	24.2	6.7	12.4
Peanut vine, without nuts	78.5	6.6	37.0	3.0	50.4	6.6	14.6	2.2	13.9
Soy bean hay	91.4	11.7	39.2	1.2	53.6	3.6	25.6	6.8	23.3
Velvet bean*	92.8	12.0	40.3	1.4	55.5	3.6	26.2	5.5	26.5
Vetch, hairy	87.7	15.7	37.1	1.9	57.1	2.6	31.8	10.3	26.2
Hay from the mixed legumes and grasses									
Clover and timothy	87.8	4.0	39.7	1.1	46.2	10.6	13.8	4.7	19.0
Cowpeas and millet*	90.3	9.3	34.7	0.9	46.0	3.9	21.9	----	----
Peas and oats	83.4	8.3	37.1	1.5	48.8	4.9	18.2	6.6	16.4
Vetch and wheat	85.0	10.7	41.1	1.3	54.7	4.1	23.2	----	----
Straw and chaff from cereals									
Barley straw	85.8	0.9	40.2	0.6	42.5	46.2	5.6	1.8	12.0
Buckwheat straw*	90.1	4.2	26.3	1.2	33.2	6.9	8.3	1.3	11.3
Millet straw*	85.8	1.0	41.7	0.6	44.1	43.1	5.8	1.8	17.3
Oat straw	88.5	1.0	42.6	0.9	45.6	44.6	5.8	2.1	15.0
Oat chaff	91.8	2.2	34.3	1.2	39.2	16.8	9.4	1.3	4.5
Rice straw	92.5	0.9	37.8	0.3	39.4	42.8	6.2	1.4	15.4
Rye straw	92.9	0.7	39.6	0.4	41.2	57.9	4.8	2.8	7.9
Wheat straw	91.6	0.7	35.1	0.5	36.9	51.7	5.0	1.3	7.4
Wheat chaff	85.6	1.1	25.7	0.6	28.2	24.6	6.7	4.0	8.4
Legume straws									
Bean*	89.5	3.6	42.4	0.7	47.6	12.2	11.7	4.2	13.6
Cowpea stover*	91.5	3.8	39.1	0.7	44.1	12.0	10.9	----	----
Soy bean stover	88.1	2.8	38.5	1.0	43.5	14.5	9.0	1.2	8.9
Miscellaneous dry roughages									
Sweet potato vines*	88.7	6.0	37.1	1.6	46.7	6.8	20.0	5.4	16.4
FRESH GREEN ROUGHAGES									
Corn, the sorghums, etc.									
Corn fodder, all analyses*	21.9	1.0	12.8	0.4	14.7	13.7	3.0	1.1	3.7
Sweet corn fodder, ears removed*	21.5	1.0	13.1	0.3	14.8	13.8	2.6	----	----
Corn husks*	36.5	1.0	22.7	0.3	24.4	23.4	2.9	0.6	5.5
Kafir fodder, all analyses*	23.6	1.1	12.4	0.4	14.4	12.1	3.8	1.6	5.1
Sweet sorghum fodder	24.9	0.7	14.1	0.6	16.2	22.1	2.4	1.1	4.1
Broom-corn fodder*	22.9	0.9	12.1	0.3	13.7	14.2	3.2	1.7	7.0
Sugar cane*	21.7	0.4	12.3	0.6	14.1	34.2	1.4	----	----

TABLE II—*Continued*

FEEDING STUFF	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Hay from the grasses, etc.									
Bermuda grass	90.3	3.7	37.9	0.8	43.4	10.7	11.4	4.0	20.0
Bluegrass, Kentucky, all analyses	86.8	4.7	43.5	1.5	51.6	10.0	13.3	5.3	21.0
Brome grass, smooth	91.5	5.0	44.2	0.9	51.2	9.2	15.8	4.2	21.5
Chess, or cheat	91.6	3.0	35.5	0.7	40.1	12.4	11.5	6.6	17.8
Crab grass	90.5	3.5	40.0	1.0	45.7	12.1	12.8	9.0	30.9
Fescue, meadow	88.3	3.5	45.2	1.1	51.2	13.6	10.9	4.6	17.2
Fowl meadow grass*	88.9	6.1	43.0	1.4	52.3	7.5	15.7	----	----
Foxtails, miscellaneous	93.2	5.6	48.0	1.7	57.4	9.2	14.9	----	----
Johnson grass	89.9	2.9	45.0	1.0	50.1	16.3	10.6	4.2	11.3
Millet, barnyard	86.5	5.1	40.5	0.8	47.4	8.3	13.3	5.5	25.3
Millet, German*	91.3	4.8	49.7	1.7	58.3	11.1	12.8	3.5	14.4
Millet, pearl, or cat-tail	87.2	4.2	43.8	0.8	49.8	10.9	10.7	----	----
Mixed grasses	87.2	4.3	44.3	1.2	51.3	10.9	12.2	3.8	16.4
Mixed grasses, rowen	86.4	7.0	39.9	1.6	50.5	6.2	19.7	3.3	16.6
Oat grass, tall or meadow oat grass	88.2	3.4	38.4	1.2	44.5	12.1	12.8	3.1	16.4
Orchard grass	88.4	4.7	41.1	1.6	49.4	9.5	12.6	4.0	19.4
Quack grass	94.1	4.2	49.7	1.1	56.4	12.4	11.7	----	----
Red top, all analyses	90.2	4.6	45.9	1.2	53.2	10.6	11.8	4.4	18.8
Rye grass, perennial*	88.0	4.4	39.0	1.6	47.0	9.7	14.7	----	----
Sedges, eastern*	90.7	2.7	41.8	0.6	45.9	16.0	9.8	2.0	9.3
Timothy, all analyses	88.4	3.0	42.8	1.2	48.5	15.2	9.9	3.1	13.6
Timothy, nearly ripe	87.5	2.2	40.7	1.1	45.4	19.6	8.3	----	----
Timothy rowen*	84.9	8.2	35.8	2.1	48.7	4.9	23.0	----	----
Hay from the smaller cereals									
Barley hay, common	92.6	4.6	48.2	0.9	54.8	10.9	11.2	----	----
Oat hay	88.0	4.5	38.1	1.7	46.4	9.3	13.4	8.0	32.7
Rye hay, all analyses*	91.9	2.9	41.1	1.1	46.5	15.0	10.7	5.0	17.0
Wheat hay*	91.9	4.0	48.5	0.8	54.3	12.6	9.9	----	----
Hay from the legumes									
Alfalfa, all analyses	91.4	10.6	39.0	0.9	51.6	3.9	23.8	5.4	22.3
Alfalfa, first cutting	91.5	9.3	39.0	0.6	49.7	4.3	22.2	5.4	22.3
Alfalfa, second cutting	92.7	11.2	40.2	0.7	53.0	3.7	23.5	5.4	22.6
Alfalfa, third cutting	91.1	10.2	37.1	0.8	49.1	3.8	23.4	5.3	22.2
Alfalfa, fourth cutting*	84.0	11.1	33.6	0.7	46.3	3.2	25.4	4.9	20.5
Alfalfa meal*	91.2	10.2	38.7	0.8	50.7	4.0	22.9	5.4	22.3
Clover, alsike, all analyses	87.7	7.9	36.9	1.1	47.3	5.0	20.5	7.0	17.4
Clover, bur	93.0	15.6	42.8	0.2	58.8	2.8	30.7	----	----
Clover, crimson, or scarlet	89.4	9.7	36.8	1.0	48.7	4.0	22.6	6.1	22.4
Clover, mammoth, red*	81.3	6.4	37.2	1.8	47.6	6.4	17.3	6.3	8.7
Clover, red, all analyses	87.1	7.6	39.3	1.8	50.9	5.7	20.5	3.9	16.3
Clover, sweet, white	91.4	10.9	38.2	0.7	50.7	3.7	23.2	6.6	12.6

TABLE II—*Continued*

FEEDING STUFF	Total dry matter in 100 lbs.	Digestible nutrients in 100 lbs.				Nutritive ratio	Fertilizing constituents in 1000 lbs.		
		Crude protein	Carbohydrates	Fat	Total		Nitrogen	Phosphoric acid	Potash
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:	Lbs.	Lbs.	Lbs.
Sunflower seed, without hulls*	95.5	23.3	17.0	33.9	116.6	4.0	44.3	----	----
Milk and its products									
Cow's milk	13.6	3.3	4.9	4.3	17.9	4.4	5.6	1.9	1.7
Skim milk, centrifugal	9.9	3.6	5.1	0.2	9.1	1.5	6.1	2.2	1.7
Buttermilk*	9.4	3.4	4.9	0.1	8.4	1.5	5.8	1.7	1.6
Whey*	6.6	0.8	4.7	0.3	6.2	6.8	1.6	1.2	2.6
Slaughterhouse by-products									
Dried blood	90.3	69.1	----	0.9	71.1	0.03	131.5	4.9	1.2
Meat-and-bone meal, 30-40% ash*	94.0	37.0	----	11.0	61.8	0.7	63.7	----	----
Pork cracklings*	95.0	52.4	----	32.6	125.8	1.4	90.2	6.1	----
Tankage, 55-60% protein	92.5	54.0	----	12.7	82.6	0.5	93.0	----	----
Tankage, below 45% protein	93.5	37.6	----	16.7	75.2	1.0	64.6	135.7	----
Miscellaneous concentrates									
Acorn, kernel and shell*	72.1	2.3	36.2	3.8	47.1	19.5	5.4	----	----
Beet pulp dried	91.8	4.6	65.2	0.8	71.6	14.6	14.2	2.4	3.8
Beet pulp, molasses	92.4	5.9	68.0	0.6	75.3	11.8	15.2	1.5	18.1
Chess, or cheat, seed*	92.3	6.2	60.6	1.5	70.2	10.3	16.8	----	----
Distillers' grains, dried, from corn	93.4	22.4	40.4	11.6	88.9	3.0	49.1	6.8	1.7
Distillers' grains, dried, from rye	92.8	13.6	38.0	6.6	66.4	3.9	37.0	8.3	2.4
Molasses, beet*	74.7	1.1	59.4	----	60.5	54.0	5.6	0.5	56.3
Molasses, cane or blackstrap	74.2	1.0	58.2	----	59.2	58.2	5.0	2.4	31.6
DRIED ROUGHAGE									
Cured corn, sorghum forage, etc.									
Corn fodder (ears, if any remaining), very dry, from barn or in arid districts	91.0	3.5	51.7	1.5	58.6	15.7	12.5	3.7	9.9
Corn fodder, medium in water	81.7	3.0	47.3	1.5	53.7	16.9	10.7	3.3	8.9
Sweet corn fodder	87.7	5.9	47.6	1.3	56.4	8.6	14.7	4.0	11.8
Corn stover (ears removed), very dry	90.6	2.2	47.8	1.0	52.2	22.7	9.4	4.5	12.9
Corn stover, medium in water	81.0	2.1	42.4	0.7	46.1	21.0	9.1	4.0	11.5
Corn leaves	76.6	3.2	40.1	1.1	45.8	13.3	11.4	----	----
Corn husks	75.3	0.6	47.3	0.3	48.6	80.0	4.6	2.3	10.2
Corn tops	82.1	3.1	45.5	1.1	51.1	15.5	9.0	----	----
Kafir fodder, dry	91.0	4.1	45.0	1.7	52.9	11.9	14.2	----	----
Kafir stover, dry	83.7	1.7	43.1	1.3	47.7	27.1	8.2	----	----
Milo fodder, dry	88.9	1.9	36.3	2.8	44.5	22.4	19.2	----	----
Sorghum fodder, dry	90.3	2.8	44.8	2.0	52.1	17.6	11.8	----	----
Sorghum bagasse, dried	88.7	0.5	52.3	0.6	54.2	107.4	5.4	----	----
Sugar-cane bagasse*	89.8	0.5	47.6	3.3	55.5	110.0	5.3	----	----

lated percentage recovery for all four soils under various experimental conditions.

TABLE VIII—*Recovery of nitrogen from nitrate of soda—comparative data for five-year period*

SOIL	LPK vs. LPKN Per cent recovery	LSPK vs. LSPKN Per cent recovery	LSFPK vs. LSFPKN Per cent recovery	PK vs. PKN Per cent recovery	SPK vs. SPKN Per cent recovery	Average per cent recovery
Cookeville	47.38	44.97	43.80	--------	--------	45.38
Crossville	*55.29	46.78	59.05	--------	--------	53.71
Gallatin	--------	92.56	†88.45	91.38	75.93	87.08
Jackson	70.94	65.19	--------	74.29	78.40	72.21

*Last four years only.
†Last three years only.

DISCUSSION OF THE RESULTS

In the case of both the Cookeville and the Crossville soil the limed cylinders were the only ones to produce crops throughout the five-year period, so that the data from the others must be considered of little or no value so far as the present object is concerned. The data from the Gallatin soil varied considerably, but the four results given in the table are considered to be the best index for this soil, the crops on which, from every point of view, appear to have been able to take up more of the nitrate nitrogen than was the case for any other soil. One estimation was also omitted for the Jackson soil because considerably out of harmony with the other four results. Inspection of the average per cent of recovery obtained, as outlined, shows a wide variation among the different soils. The Gallatin soil easily comes first, with a recovery of 87.00 per cent; the Jackson soil is second, with an average recovery of 72.21 per cent; the Crossville soil ranks third, with a recovery of 53.71 per cent; and the Cookeville soil comes last, with a recovery of only 45.38 per cent.

There seems to be little correlation between these results and the physical nature of the soil. The Gallatin soil is of excellent texture and structure, but so is the Crossville, which ranks next to the lowest in nitrogen recovery. The Jackson soil, which easily ranks second in recovery, is considered to have decidedly the poorest texture of all the soils, but resembles in this particular the Cookeville soil more than any other. The latter, however, gave the lowest recovery, which was only a little more than half that of the Gallatin soil, and not two-thirds that of the Jackson soil. The only important correlating factor noticeable to the writer is crop yield; that is, the percentage of nitrogen recovery is in harmony with the natural productiveness of the soils, being greatest for the fertile Gallatin soil and least for the very poor Cookeville soil. It should be borne in mind, however, that all four soils proved to be in considerable need of available nitrogen. Of course with an excessive supply naturally present in the Gallatin

soil, for example, other and even opposite conclusions would be expected, as was found by Lipman and Blair* in the case of rich garden soil so abundantly supplied with nitrogen as to give the lowest response to the applications of nitrate.

RECOVERY OF ORGANIC NITROGEN

The availability of the nitrogen of farm manures applied to the soil is very different from that of nitrate of soda. The latter is ready for immediate use by plants and, as just indicated, seems to be taken up most nearly completely where there is the greatest mass of roots to come into contact with the salt as it is carried through the soil in water solution. On the other hand, insoluble organic nitrogen must undergo a complete change, and for the most part is probably converted into the nitrate form before being taken up by plants. The conversion, due almost entirely to bacteria, which are dependent, among other things, on a good supply of air, goes on slowly in farm manures, and this accounts for their reputation for "lasting" effects. For several reasons, such as variation in air and moisture supplies, different soils would be expected to show in the crop returns different percentages of recovery of the organic nitrogen applied.

Five cylinders in each series received manure, one application at the outset, in 1909, and another in 1911, at the close of the second year. To three of each set of five, an application of straw was made along with the manure; or these three may be said to have received applications of "strawy" manure. Since the Cookeville and Crossville soils produced crops regularly throughout the five-year period only where limed, the cylinders which received manure without lime are omitted from the calculations for all four soils. There are left, then, for each kind of soil four cylinders which are suitable to the purpose. Since there were corresponding cylinders similarly treated, except that neither straw nor manure was used, the percentage recovery of the organic nitrogen can be calculated as in the case of the nitrate nitrogen. Table IX gives the data thus obtained.

TABLE IX—*Recovery of organic nitrogen—comparative data for five-year period*

SOIL	L vs. LF Per cent recovery	L vs. LSF Per cent recovery	LPK vs. LSFPK Per cent recovery	LPKN vs. LSFPKN Per cent recovery	Average per cent recovery
Cookeville	34.13	34.18	26.12	24.84	29.82
Crossville	41.92	37.78	32.58	25.81	34.52
Gallatin	50.83	38.36	29.88	31.25	37.58
Jackson	19.34	20.94	22.06	33.18	23.88

*N. J. Exp. Sta. Bul. 289.

DISCUSSION OF RESULTS

Table IX shows that the soils differed widely with respect to their influence upon the recovery of organic nitrogen. The Gallatin soil gave the highest recovery, 37.58 per cent; the Crossville soil is a close second, with a recovery of 34.52 per cent; the Cookeville soil ranks third, with a recovery of 29.82 per cent; and the Jackson soil comes last, with a recovery of only 23.88 per cent. It is worthy of note that the soils which were most alike in physical condition gave similar recoveries, the open and porous Gallatin and Crossville soils ranking highest on the one hand, and the close, silty Jackson and Cookeville soils ranking lowest on the other.

Fig. 5 shows the comparative recoveries of both the organic and the inorganic nitrogen applied to each soil type.

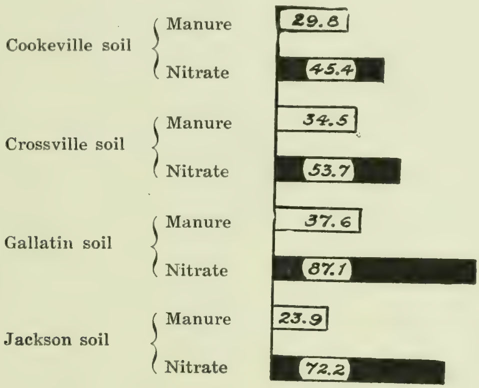


FIG. 5—PERCENTAGE RECOVERY OF ORGANIC AND INORGANIC NITROGEN IN FIVE-YEAR PERIOD

THE RATIO BETWEEN CROP NITROGEN AND CROP YIELD

The ratio between the nitrogen content of the crops and the total yield of dry substance proved of interest because, as shown in

TABLE X—*Utilization of nitrogen by crops grown on different soils—comparative data for five-year period from the ten limed cylinders of each type*

SOIL	Crop yield (air-dry substance)	Nitrogen in crops	Air-dry crop per gram of nitrogen	Dry substance per gram of nitrogen
	Grams	Grams	Grams	Grams
Cookeville	7926.99	77.8112	101.88	91.69
Crossville	8221.02	79.9869	102.78	92.50
Gallatin	13990.28	132.3349	105.72	95.15
Jackson	11922.78	89.4196	133.34	120.01

TABLE XI—*Utilization of nitrogen from (1) manure and (2) nitrate of soda—comparative data for five-year period*

SOIL	Fertilizer source of nitrogen	Nitrogen applied	Air-dry crop increase	Nitrogen increase	Nitrogen recovery	Calculated increase of dry substance per gram of nitrogen utilized
		Grams	Grams	Grams	Per cent	Grams
Cookeville	Manure*	29.9700	1126.29	9.8746	32.95	102.65
Cookeville	Nitrate of soda†	17.5110	812.60	7.9479	45.39	92.02
Crossville	Manure*	29.9700	1269.74	10.6259	35.45	107.54
Crossville	Nitrate of soda†	17.5110	1122.85	10.4167	59.49	97.01
Gallatin	Manure*	29.9700	1389.21	12.0049	40.05	104.15
Gallatin	Nitrate of soda‡	21.0132	1840.47	18.2664	86.93	90.68
Jackson	Manure*	29.9700	672.54	4.9763	16.61	121.63
Jackson	Nitrate of soda§	23.3480	2429.19	16.8585	72.21	129.68

*Experiment Nos. 1, 16, 12, and 3, 5, 6.

†Experiment Nos. 6, 8, 12, and 17, 10, 14.

‡Experiment Nos. 6, 7, 11, 12, and 17, 9, 13, 14, but only last three years of 6 and 17.

§Experiment Nos. 7, 8, 11, 12, and 9, 10, 13, and 14.

Table X, the Jackson soil produced nearly a third more crop per gram of nitrogen utilized than did the other kinds of soil. The average for the Cookeville, Crossville, and Gallatin soils is only 93.11 grams of dry crop per gram of nitrogen, while for the Jackson soil there were produced 120.01 grams of dry crop per gram of nitrogen.

In Table XI is shown the calculated dry matter per gram of nitrogen utilized from both nitrate of soda and manure for each type. The figures show, on the average, for the Cookeville, Crossville, and Gallatin soils that one gram of nitrogen utilized from nitrate of soda produced 93.24 grams of dry substance, and that one gram of nitrogen utilized from the manure produced 104.78 grams of dry substance. In the case of the Jackson soil, however, one gram of utilized nitrogen from nitrate of soda produced 129.68 grams of dry substance, and one gram of nitrogen utilized from manure produced a gain of 121.63 grams of dry substance.

The grain and straw of the wheat crops grown in both 1912 and 1913 were analyzed separately, and Table XII gives the nitrogen content of these parts for each type of soil. Also there is given the average nitrogen content of the whole wheat crop for the four years grown and of the millet hay for five years. From these data it is evident that both the grain and the straw of the wheat crops from the Jackson soil are appreciably and consistently lower in nitrogen than the same products from any of the other three soils. Similarly the nitrogen content of the millet hay is consistently the lowest for the

Jackson soil. The close accord of the results for the Crookeville, Crossville, and Gallatin soils is noticeable. All the data show that the Jackson soil is quite different from the others; and the conclusion is drawn that the nature of the soil may have an important effect on the composition of the crop. However, in view of the results obtained by others,* as well as the close agreement in the composition of the crops from three of the four soils investigated here, it is evident that the Jackson soil is exceptional in this respect.

TABLE XII—*Nitrogen content of wheat and millet crops when grown on different soils—data from air-dry crops grown in experiments Nos. 3, 5, 6, 8, 10, 12, 14, and 17*

SOIL	Wheat				Wheat—whole crop—four year averages	Millet hay—five year averages
	Harvest of 1912		Harvest of 1913			
	Grain	Straw	Grain	Straw		
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Cookeville	1.81	0.34	2.13	0.54	0.958	1.034
Crossville	1.82	0.42	2.05	0.51	0.996	0.951
Gallatin	1.82	0.31	2.07	0.44	0.949	0.894
Jackson	1.59	0.21	1.93	0.34	0.782	0.744

SOIL NITROGEN RESULTS

CONSIDERATIONS LEADING TO THE ANALYTICAL DATA

At the outset of the experiments both surface-soil and subsoil samples, the latter at different depths, were taken from each type for analysis. The subsoils were laid down in 1908 and the samples were taken at that time. The surface-soil samples were taken in 1909, previous to the manurial treatment, and, as in the case of the subsoil, each was supposed to represent the average of the mixture for that type. A better plan of procedure would have been to analyze for nitrogen the soil of each cylinder separately, and so avoid errors which can easily follow from a single sampling and analysis. For this reason the writer can not lay the stress he would like to on the absolute results which might be calculated from the early sampling, but he wishes to emphasize in particular only such conclusions as can be brought out by comparative data.

In 1911, previous to the second application of manure and straw, surface-soil samples were taken from each cylinder. In 1914, after the harvest of the millet crop, samples were taken not only from the surface soil of each cylinder, but also from the subsoil at both the

*See "Environmental Influence on the Physical and Chemical Characteristics of Wheat," by J. A. LeClerc and P. A. Yoder, Jour. of Agr. Research, Vol. 1, No. 4, pp. 275-291. Their results "emphasize the relatively small role played by the soil in influencing the protein content of wheat." A similar conclusion was also reached by Lipman and Blair, N. J. Sta. Bul. 289, p. 45.

6-to-12-inch depth (first six inches of subsoil) and the 12-to-24-inch depth, with the exception of the estimations summarized in Table XVII for the 12-to-24-inch depth. All the nitrogen estimations calculated to a moisture-free basis are given in Tables XIII and XIV (see Appendix). These estimations were made with special care by the Kjeldahl method as modified by Gunning. Ten-gram samples were always used, and pains were taken to insure throughout the period the same actual strength of standard acid used as a basis for the titrations. Owing, however, to errors, apparently unavoidable in both sampling and analysis—errors which are appreciable where an effort is made to determine the nitrogen to the fourth decimal—too much value can easily be put upon a single result. It is, therefore, important to draw conclusions only where the results from several cylinders can be averaged; in fact, the larger the number the better.

THE LOSS OF NITROGEN FROM THE SURFACE SOIL UNDER VARIOUS CONDITIONS

In Table XV is given the nitrogen found in each type of soil under several different conditions, which will be considered as follows:

1. CROPPING VERSUS BARE FALLOW

In this comparison there are for each of the four types of soil five cropped cylinders which received the same manurial treatment as five of the bare-fallow cylinders. The results given in Table XV show that without exception the soils lost decidedly more nitrogen under bare fallow than where the two crops, a small grain and millet, were removed each year. The losses under bare fallow varied from about one and one-half times the loss under cropping for the Gallatin soil to about six times for the Crossville soil.

In reviewing the investigations at Rothamsted, Dyer called particular attention to the correlation between increased crop production and increase in nitrogen content of the soil, but attributed the increase solely to the increase in crop residues.* This explanation will account for only a part, perhaps one-third, of the nitrogen found to be conserved in the cylinder experiments. An additional reason for this result is, therefore, suggested, as follows: Under cropping the average moisture content of the soils was observed to be considerably less than where no crops were grown. The higher moisture content of the uncropped cylinders results in a longer period favorable to nitrification, and consequently increased total production. Furthermore, with a higher moisture content less rain would be required to produce leaching. There would, therefore, not only be more nitrate produced, but a greater chance for loss by leaching under bare fallow than under cropping.

Figure 6 shows the comparative losses of soil nitrogen suffered by each type of soil in the five-year period under both cropped and uncropped conditions.

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*Bernard Dyer, Results of Investigations on Rothamsted Soils, Office of Exp. Stas. Bul. 106, p. 48.

TABLE XV—*Loss of nitrogen from the surface soil under various conditions—all cropped except Series B*

SOIL	Per cent nitrogen 1909*	Per cent nitrogen 1914	Loss in grams per cylinder for five-year period
A. Cropped. Experiment Nos. 6, 8, 10, 12, and 14. Treatments comparable to those in Series B			
Cookeville	0.0799	0.0759	2.1108
Crossville	0.0841	0.0819	1.1735
Gallatin	0.1521	0.1282	12.4268
Jackson	0.0652	0.0660	+ 0.4060
Average	0.0953	0.0880	3.8263
B. Uncropped. Experiment Nos. 18, 20, 21, 22, and 23. Treatments comparable to those in Series A			
Cookeville	0.0799	0.0671	6.7547
Crossville	0.0841	0.0725	6.1873
Gallatin	0.1521	0.1171	18.1983
Jackson	0.0652	0.0569	4.2118
Average	0.0953	0.0784	8.8380
C. Phosphate and potash applied. Experiment Nos. 6, 7, 8, 11, and 12. Treatments comparable to those in Series D			
Cookeville	0.0799	0.0754	2.3739
Crossville	0.0841	0.0813	1.4936
Gallatin	0.1521	0.1270	13.0474
Jackson	0.0652	0.0641	0.5583
Average	0.0953	0.0870	4.3683
D. Neither phosphate nor potash applied. Experiment Nos. 1, 4. 5, 15, and 16. Treatments comparable to those in Series C			
Cookeville	0.0799	0.0745	2.8487
Crossville	0.0841	0.0827	0.7468
Gallatin	0.1521	0.1265	13.3074
Jackson	0.0652	0.0639	.6598
Average	0.0953	0.0869	4.3907

*Nitrogen applied in manure and straw in 1909 and 1911 included.

TABLE XV (*Continued*)

SOIL	Per cent nitrogen		Loss in grams per cylinder for five-year period
	1909*	1914	
E. Limed. Experiment Nos. 1, 3, 8, 10, 12, 14, and 16. Treatments comparable to those in Series F			
Cookeville	0.0784	0.0729	2.9024
Crossville	0.0826	0.0819	0.3734
Gallatin	0.1506	0.1282	11.6469
Jackson	0.0637	0.0660	+ 1.1671
Average	0.0938	0.0873	3.4389
F. Unlimed. Experiment Nos. 9, 10, 13, 14, and 17. Treatments comparable to those in Series E			
Cookeville	0.0784	0.0736	2.5330
Crossville	0.0826	0.0816	0.5334
Gallatin	0.1506	0.1253	13.1547
Jackson	0.0637	0.0605	1.1164
Average	0.0938	0.0853	4.3344
G. Nitrated. Experiment Nos. 9, 10, 13, 14, and 17. Treatments comparable to those in Series H			
Cookeville	0.0799	0.0754	2.3739
Crossville	0.0841	0.0821	1.0669
Gallatin	0.1521	0.1273	12.8915
Jackson	0.0652	0.0660	+ 0.4061
Average	0.0953	0.0877	3.9816
H. Unnitrated. Experiment Nos. 6, 7, 8, 11, and 12. Treatments comparable to those in Series G			
Cookeville	0.0799	0.0754	2.3739
Crossville	0.0841	0.0813	1.4936
Gallatin	0.1521	0.1270	13.0474
Jackson	0.0652	0.0641	0.5583
Average	0.0953	0.0870	4.3683

*Nitrogen applied in manure and straw in 1909 and 1911 included.

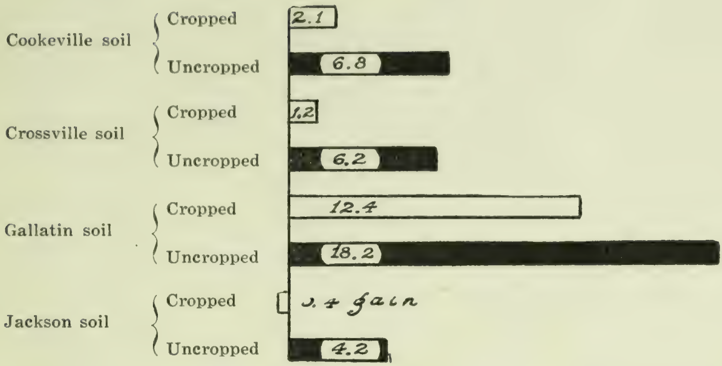

FIG. 6—LOSSES OF NITROGEN FROM SURFACE SOIL IN GRAMS PER CYLINDER IN FIVE-YEAR PERIOD UNDER BOTH CROPPED AND UNCROPPED CONDITIONS

2. THE EFFECT OF ACID PHOSPHATE AND MURIATE OF POTASH

The complaint is sometimes made by farmers that commercial fertilizers have a "burning" effect on the soil, much as lime is said to have. Complete experiments to test this possibility, so far as acid phosphate and muriate of potash are concerned, would include a series without crops, but unfortunately this was omitted from the plans.

An annual application of both acid phosphate and muriate of potash was made to five cropped cylinders (Exp. Nos. 6, 7, 8, 11, and 12) for each type of soil. Five other cylinders (Exp. Nos. 1, 4, 5, 15, and 16) received none, but otherwise the treatments were the same as for those receiving the phosphate and potash. For both the Cookeville and the Crossville soil this mixture produced an increased yield of nearly 25 per cent, but for the Gallatin soil the increase was only 5 per cent, while no increase is noted for the Jackson soil.

The results show that under cropping the nitrogen content of the soils treated with phosphate and potash was at the end of the five-year period practically the same, on the average, as that of the untreated soils.

3. THE EFFECT OF GROUND LIMESTONE

Liming is generally considered to accelerate oxidation, including nitrification, in the soil. Conclusive data with regard to the extent of this action are, however, not abundant. In order to eliminate the crop factor, experiments without cropping are necessary. Unfortunately only in the case of the Jackson soil are there uncropped cylinders furnishing this kind of comparison. These are Experiment Nos. 18, 21, 25, and 29, which included the application of ground limestone, and Nos. 24, 26, 27, and 28, without the application. At

the end of the five-year period the average per cent of soil nitrogen for the four limed cylinders was 0.0600, and for the four unlimed 0.0587. Another series of open-air experiments at this Station, experiments in which no crops were grown, gave, at the end of two years, the following results:

SERIES	CaO applied per acre in form of ground limestone	Total nitrogen Per cent
1	2 tons	.1127
2	8 tons	.1076
3	None	.1135

The soil used was a Cumberland loam from the Station farm at Knoxville. Each series gives the average result from four cylinders each of 1-10,000 acre surface area. The data obtained from both the Jackson soil and the Cumberland loam agree, therefore, in indicating that where no crop is grown, ground limestone produces a small but measurable decrease in soil nitrogen.

As given in Table XV, under cropping three of the four soils at the end of the five-year period show an increase of soil nitrogen where the ground limestone was applied, the average per cent of nitrogen for the four soils being 0.0873 for the limed as compared with 0.0853 for the unlimed. In short, the slight loss of soil nitrogen induced by the ground limestone per se was more than offset by the conservation brought about by increased crop production.

4. THE EFFECT OF NITRATE OF SODA

To determine the effect of nitrate of soda per se on the content of soil nitrogen, Experiment Nos. 22 and 23 (see Table V), which received an annual top-dressing of nitrate, can be compared with Nos. 18 and 20, which received none. There are, therefore, eight nitrated and uncropped cylinders, two for each kind of soil, which can be compared with eight others that were unnitrated. At the end of the five-year period, the average nitrogen content of the eight nitrated cylinders was 0.0773 per cent and of the eight unnitrated 0.0762 per cent. The results show, therefore, a loss of soil nitrogen attributable to the applications of the nitrate.

In the summary of the results obtained under cropping, none of the soils shows less nitrogen, on the average, where nitrated than where unnitrated, but the difference is small, only 0.0007 per cent, on the average, for the four types. This difference, however, allows the conclusion to be drawn that in these experiments any loss caused by the nitrate per se was somewhat more than offset by the conservation of soil nitrogen brought about by increased crop production.

TABLE XVI—*Loss of nitrogen from first six inches of subsoil under various conditions*

SOIL	Per cent nitrogen 1908	Per cent nitrogen 1914	Calculated loss in grams per cylinder in five-year period
A. Cropped. Experiment Nos. 3, 6, 8, 10, 12, and 14. Treatments comparable to those in Series B			
Cookeville	0.0300	0.0281	1.1883
Crossville	0.0607	0.0599	.5000
Gallatin	------	0.0736	------
Jackson	0.0324	0.0293	1.8858
Average		0.0477	
B. Uncropped. Experiment Nos. 18 to 23, inclusive. Treatments comparable to those in Series A			
Cookeville	0.0300	0.0261	2.4375
Crossville	0.0607	0.0561	2.8750
Gallatin	------	0.0668	------
Jackson	0.0324	0.0309	.9125
Average		0.0450	
C. Nitrated, cropped. Experiment Nos. 9, 10, 13, 14, and 17. Treatments comparable to those of Series D			
Cookeville	0.0300	0.0276	1.5000
Crossville	0.0607	0.0584	1.4375
Gallatin	------	0.0747	------
Jackson	0.0324	0.0312	0.7300
Average		0.0480	
D. Unnitrated, cropped. Experiment Nos. 6, 7, 8,* 11, and 12. Treatments comparable to those of Series C			
Cookeville	0.0300	0.0271	1.8125
Crossville	0.0607	0.0585	1.3750
Gallatin	------	0.0725	------
Jackson	0.0324	0.0289	2.1292
Average		0.0468	

*No. 8 omitted from both Cookeville and Crossville calculations.

TABLE XVI (*Continued*)

SOIL	Per cent nitrogen 1908	Per cent nitrogen 1914	Calculated loss in grams per cylinder in five-year period
E. Manured, uncropped. Experiment Nos. 19 and 20. Treatments comparable to those in Series F			
Cookeville	0.0300	0.0262	2.3750
Crossville	0.0607	0.0552	3.4375
Gallatin	------	0.0698	------
Jackson	0.0324	0.0295	1.7642
Average		0.0452	
F. Unmanured, uncropped. Experiment Nos. 18 and 21. Treatments comparable to those in Series E			
Cookeville	0.0300	0.0254	2.8750
Crossville	0.0607	0.0578	1.8125
Gallatin	------	0.0691	------
Jackson	0.0324	0.0310	0.9517
Average		0.0458	
G. Manured, cropped. Experiment Nos. 2, 3, 5, 6, and 7. Treatments comparable to those in Series H			
Cookeville	0.0300	0.0273	1.6875
Crossville	0.0607	0.0592	0.9375
Gallatin	------	0.0746	------
Jackson	0.0324	0.0294	1.8140
Average		0.0476	
H. Unmanured, cropped. Experiment Nos. 1, 4, 7, 8, 9, and 10. Treatments comparable to those in Series G			
Cookeville	0.0300	0.0274	1.6250
Crossville	0.0607	0.0583	1.5000
Gallatin	------	0.0714	------
Jackson	0.0324	0.0285	2.3725
Average		0.0464	

LOSSES OF NITROGEN FROM THE SUBSOIL AT DIFFERENT DEPTHS

THE 6-TO-12-INCH DEPTH

Table XIV gives the nitrogen content of the subsoil from the 6-to-12-inch depth of each cylinder six years after being laid down. Also there is given the nitrogen content of an average sample for each type at the outset of the experiments, except for the Gallatin, which was, unfortunately, lost. The results for the Cookeville, Crossville, and Jackson soils all agree in indicating an appreciable loss of nitrogen at this depth. Table XVI shows the subsoil losses sustained under various conditions, which may be discussed briefly as follows:

CROPPING VERSUS BARE FALLOW

The effect of cropping on the loss of nitrogen from the subsoils resembles that from the surface soils, except that the losses from the latter are more pronounced than from the former. The average per cent of subsoil nitrogen from twenty-four cropped cylinders, six from each type of soil, was 0.0477, while the average per cent for the corresponding uncropped cylinders was 0.0450. Cropping, therefore, appreciably conserved the nitrogen supply of the subsoil.

THE EFFECT OF NITRATING

Comparison can be made under cropped conditions between five nitrated and five unnitrated cylinders for each type of soil. The results—C and D of Table XVI—show a higher nitrogen content in the subsoil of the nitrated cylinders for three of the four soil types. The average per cent of nitrogen for all four subsoils at the end of the five-year period was 0.0480 for the nitrated cylinders and 0.0468 for the unnitrated.

The higher percentage of the nitrated cylinders is attributed, as previously, to a conservation of nitrogen in the subsoil through increased crop production.

THE EFFECT OF MANURING

The effect of manure applied to the surface soil on the nitrogen content of the subsoil is shown by the results obtained under both cropped and uncropped conditions. Where no crops were grown—E and F of Table XVI—little appreciable difference, as the average for all four types, was found between the nitrogen content of the subsoil of the manured and unmanured cylinders, the manured cylinders giving an average percentage of 0.0452, as compared with 0.0458 for the unmanured. Since for two of the soil types there is a slightly higher nitrogen content under manuring, and for two others a slightly lower content, no special stress can be placed on the average difference, which is favorable to the unmanured cylinders. It is possible, however, that the period of nitrification and consequent increased loss by leaching would be greater for the manured cylinders than for the unmanur-

ed, due to the slightly higher moisture content, which would be expected in the former.

Under cropping—G and H of Table XVI—the average nitrogen content of the subsoil of all four soil types was found to be 0.0476 per cent for the manured cylinders and 0.0464 per cent for the unmanured. This result is in harmony with the others obtained; that is, subsoil as well as surface-soil nitrogen is conserved through increased crop production.

THE 12-TO-24-INCH DEPTH

Table XVII gives a summary of the analytical data from the second foot of each soil type. The results indicate a small probable loss from this depth, but owing to the uncertainty arising from the analysis of a single composite sample of each type of soil, as was the case for the 1908 determinations, no further conclusions seem warranted to the writer.

TABLE XVII—*Loss of nitrogen from second foot (all cylinders, regardless of treatment)*

SOIL	Total nitrogen		
	1908	1912	1914
	Per cent	Per cent	Per cent
Cookeville	0.0214	------	0.0186
Crossville	0.0421	------	0.0416
Gallatin*	0.0662	0.0654	0.0650
Jackson	0.0247	------	0.0249
Average	0.0386		0.0375

*The figures used for the Gallatin soil were obtained in another series of similar experiments with eight cylinders of this soil. Only the 1912 and 1914 results are available, the per cent for 1908 being calculated on the assumption that the loss of nitrogen was constant throughout the period.

QUANTITATIVE RELATIONSHIP BETWEEN CROP YIELD AND TOTAL NITROGEN CONSERVED IN SOIL AND SUBSOIL

There appears to be throughout the experiments a direct relationship between the size of the crop and the quantity of nitrogen conserved, so that, with other factors constant, the greater the crop, the greater will be the conservation. In Table XVIII there are given for each soil type the data showing the saving of nitrogen in the surface soil and the first six inches of subsoil combined per gram of crop harvested. The average for the four types is 7 mgs of nitrogen per gram of air-dry crop. The results from the Cookeville, Crossville, and Gallatin types are in very close accord, and probably represent the average expectancy much more than the results from the Jackson type. With the latter eliminated, the average combined saving of soil

TABLE XVIII—*The conservation of nitrogen through cropping. Calculations based on the changes in nitrogen content of surface soil and first six inches of subsoil in the five-year period*

SOIL	Average air-dry crop per cylinder for five-year period. Exp. Nos. 6, 8, 10, 12, and 14	Increased loss of nitrogen per cylinder where no crops were grown. Exp. Nos. 18 to 23, inclusive	Nitrogen conserved per gram of air-dry crop harvested
	Grams	Grams	Grams
Cookeville	796.57	6.3689	0.0080
Crossville	826.94	7.7389	0.0094
Gallatin	1379.56	10.5814	0.0077
Jackson	1171.53	3.5227	0.0030
Average			0.0070

and subsoil nitrogen becomes 8.4 mgs per gram of air-dry crop, or 9.3 mgs per gram of dry substance.

CONSERVATION OF SOIL NITROGEN AS A FACTOR IN THE INTERPRETATION OF PLOT AND CYLINDER EXPERIMENTAL RESULTS

Definite figures in regard to the amount of soil nitrogen conserved by cropping are of importance both to the practical farmer who has long been advised to grow winter cover crops to prevent waste of soil nitrogen, and to the scientific worker in the interpretation of both plot and cylinder experiments in the field. In fact, the extent to which an increase in crop conserves the soil supply of nitrogen seems not to have been sufficiently stressed, if realized, in the past. In a recent bulletin by Lipman and Blair* the higher nitrogen content of the soils of the green manure cylinders was attributed solely to the leguminous green manure crops. In view, however, of the findings reported in this bulletin, the higher content can be accounted for in large part through the conservation of the soil nitrogen induced by the increased crop production.

The importance of this suggestion causes the writer to consider in some detail the interpretation of certain of the results obtained with the eight different soils used in their experiments.

In 1907, at the outset of the experiments the average per cent of nitrogen in the eight soils was 0.0945. In 1912 the average for the "check" cylinders was 0.0712 per cent and for the "green manure" cylinders 0.0817 per cent. Since 200 pounds or 90,720 grams of soil were used per cylinder, 9.5256 grams of soil nitrogen per cylinder need to be accounted for. The authors state†: "Since no nitrogen has been ap-

*Lipman and Blair, Cylinder Experiments Relative to the Utilization and Accumulation of Nitrogen. N. J. Exp. Sta. Bul. 289 (1916).
†N. J. Exp. Sta. Bul. 289, p. 37.

plied to these cylinders it must be admitted that this extra amount has been accumulated by the leguminous crops grown on these cylinders." In the consideration of this subject the fact should be kept in mind that under both sets of experimental conditions all the soils, with one exception, were lower in nitrogen at the end of the six years than at the outset. To the 9.5256 grams of soil nitrogen must be added the gain in nitrogen found in the increased crops of the green manure cylinders, or 3.3173 grams on the average per cylinder for the eight soils. The total nitrogen to be accounted for, therefore, is 12.8429 grams. To account for this amount without regard to the conservation of soil nitrogen through increased crop production, either large green manure crops are required, or the assumption must be made that nitrogen was somehow deposited in the soil in excess of that which would be expected from the leguminous green manure crops obtained. The general opinion,* however, among agricultural authorities is that only a fraction of the nitrogen found in a leguminous field crop can be credited to the atmosphere and that perhaps the larger part is furnished by the initial nitrogen stores of the soil. Also there is reason to believe that the richer the soil in available nitrogen the less will the legume take from the air. If the assumptions be made, however, that in the experiments of Lipman and Blair one-half the total nitrogen of the green manure crops come from the air and that none was lost by leaching, how large crops are required to meet the conditions found? With one-half the nitrogen coming from the soil and one-half from the air the total nitrogen in the tops and roots of the green manure crops would amount to 25.6858 grams per cylinder for the five-year period, or 5.1372 grams per cylinder per annum. Two-thirds of this nitrogen, or 3.4248 grams, may be allowed to the harvestable part. Since the dry matter of an immature crop is considerably higher in nitrogen than the averages published for common hay crops a nitrogen content of 3 per cent is assumed.† On this basis there are required green manure crops furnishing 114.16 grams of dry matter per cylinder per annum, or 3655 pounds per acre, an amount which could not be described as "small, moderate" and "none large."‡

The question may now be asked, if the conservation factor be taken into consideration how large crops will be required?

Assuming that all the crops of the first six years should be included, the writer has calculated from the data of the bulletin that on the average for all eight soils there were produced in this period 471 grams more of dry matter per cylinder by the "green manure" cylinders than by the "check" cylinders. Using the factor found by the writer, the soil nitrogen conserved by 471 grams of dry matter

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*See, for example, the statements by various station workers, as recently compiled by Henry G. Bell, Agronomist, Middle West Soil Improvement Committee of the National Fertilizer Association, Chicago, Ill.

†See The Growth of Crimson Clover, by Charles L. Penny. Del. Exp. Sta. Bul. 67.

‡N. J. Exp. Sta. Bul. 289, p. 59.

would be 471 x 9.3 mgs, or 4.3803 grams.* This leaves 5.1453 grams of soil nitrogen and 3.3171 grams of crop nitrogen to be accounted for by two factors: (1) the further conservation of the soil supply by the green manure crops, and (2) the addition of nitrogen through fixation of atmospheric nitrogen by the green manure crops. Assuming as before that two-thirds of the nitrogen would be found in the harvestable part and that one-half the nitrogen of the total crop came from the air, the writer has calculated that an average annual crop of 1,800 lbs. per acre would be ample to meet the conditions. If, however, a gram of dry matter in the crops grown would under their conditions conserve more than 9.3 mgs the necessary green manure crop would be further reduced. Also more than 3 per cent nitrogen might be found in the dry matter of the green manure crops and this would cause another reduction in the crop required. At all events the writer feels justified in the conclusion that only a moderate utilization of atmospheric nitrogen by the leguminous crops grown may have been required in order to explain the New Jersey results.

THE COMPARATIVE LOSSES OF NITROGEN FOR THE DIFFERENT TYPES OF SOIL

The comparative losses of nitrogen suffered by each type of soil can be most satisfactorily studied from the data obtained in the last three years of the experiments. The reason for this is that only in 1911 and 1914 were nitrogen determinations made for each cylinder. Also if the calculations be limited to cropped and limed cylinders, which alone produced crops consistently throughout the period, a comparative study can be made with regard to the relationship between the loss of soil nitrogen and the nitrogen found in the crops produced. Table XIX has been prepared, therefore, to show for each type of soil (1) the average amount of nitrogen in the surface soil of the ten limed and cropped cylinders immediately after the manurial treatments of the fall of 1911; (2) the amount of nitrogen in the same soil at the end of three years; and (3) the nitrogen found in the crops for the same period after both the nitrogen contained in the seed sown and that calculated to be recovered from the surface dressing of nitrate of soda is deducted.

The calculations of Table XIX show that for all four types of soil, more nitrogen was found in the crops than can be accounted for by loss from the surface soil. If the losses of nitrogen from the subsoil be included, more nitrogen was lost from the Cookeville, Crossville and Gallatin cylinders than can be accounted for in the crops grown; that is, there were material losses by leaching, in spite of the fact that both winter and summer crops were grown. In the case of the Jackson soil, however, the remarkable result is obtained of an actual increase of surface-soil nitrogen, with only moderate losses from the

*In the experiments by Lipman and Blair 200 lbs. of surface soil were used per cylinder of 1-14,520 acre surface area. This rate is practically the same as the sum of the surface soil and first six inches of subsoil in the writer's experiments; that is, in each series there would be a little less than 3,000,000 lbs. per acre.

TABLE XIX—*The amount of nitrogen lost from the surface soil and the amount recovered by crops in the three-year period* 1911-1914. *Results from the aggregate of the ten limed and cropped cylinders for each soil type*

SOIL	Nitrogen in surface soil		Soil loss	Nitrogen found in crops (N in seed sown and that recovered from nitrate of soda deducted)
	1911	1914		
	Grams	Grams	Grams	Grams
Cookeville	434.5036	404.6478	29.8558	32.5655
Crossville	467.8582	450.3412	17.5170	32.3176
Gallatin	719.0515	670.1063	49.9452	55.6300
Jackson	345.6812	347.3935	+ 1.7123	42.2610

subsoil—losses entirely insufficient to account for the nitrogen found in the crops.

Possible sources of nitrogen, such as nitrogenous materials gathered by ants and other insects from sources outside the cylinders, were considered by the writer, but he was unable to discover anything which would not apply with equal or more force to the other soil types. Small red ants were occasionally observed in the cage, both inside and outside the cylinders of all the soils, but they were apparently in small numbers. The soil outside of the cylinders was kept bare and was quite poor, and there were no known sources near by from which ants could get special supplies of food. In addition the close, silty nature of the Jackson soil, with its poor drainage qualities, seemed unfavorable to animal life as compared with either the Crossville or Gallatin type, in particular. Since there is nothing to suggest capillary action as being responsible for the augmentation of nitrogen, the conclusion appears warranted that considerable atmospheric nitrogen was "fixed" in the Jackson soil and became available to the crops grown.

The peculiarities of this soil with regard to physical character and chemical composition have been referred to previously, but it may be of interest to note again that this was the only soil to give a slightly alkaline reaction by the Veitch test, all the others showing "acidity."

SUMMARY

GENERAL CONSIDERATIONS

1. Four distinct types of soil, designated as Cookeville, Crossville, Gallatin and Jackson, were selected for a study of nitrogen economy.

2. Each soil was removed in layers as found in the field, transported to Knoxville, and placed in cylinders sunk four feet in the ground. Each cylinder enclosed a surface area of 1/10,000 acre. Full

exposure to the weather was permitted, but protection was provided from birds, etc. No artificial watering was given.

3. Ten successive crops were planted in each of 69 cylinders, while 31 were kept bare. The crops were oats the first season, wheat four seasons, and millet grown in the summer after each of the five small-grain crops.

4. The amount of ground limestone applied and the other manurial treatments as given were moderate and well within the limits of farm practice.

CROP RESULTS

5. The largest crops were produced by the Gallatin soil, which had decidedly the highest content of total nitrogen, but the yields decreased very rapidly in the course of the five years. The second largest yields were obtained from the Jackson soil, which had the lowest nitrogen content—only a little more than one-third of that of the Gallatin soil. The Jackson soil, however, maintained a more constant yield than any other, and in the last two years the crop equalled those from the Gallatin soil. The Cookeville and Crossville soils proved to be the least productive, and were practically on an equality in this respect.

6. For the Cookeville and Crossville soils constancy of yield was obtained only on the limed cylinders. The results given by the ten limed and cropped cylinders of each of the four types were used, therefore, in determining the percentage of nitrogen recovery from manurial applications and in certain other calculations.

7. The recovery by crops of the nitrogen applied in the form of sodium nitrate varied with the kind of soil as follows:

Cookeville	45.38 per cent
Crossville	53.71 per cent
Gallatin	87.08 per cent
Jackson	72.21 per cent

The results are correlated with the productiveness of the soils; that is, the more productive the soil the greater the root development to intercept the nitrate—the greater the percentage of nitrate nitrogen recovered.

8. The recovery by crops of nitrogen from the organic materials —manure and manure plus straw—varied with the kind of soil as follows:

Cookeville	29.82 per cent
Crossville	34.52 per cent
Gallatin	37.58 per cent
Jackson	23.88 per cent

The results are correlated with the physical nature of the soils; that is, the more open and porous soils show the highest recovery.

9. The ratio between the nitrogen content and the dry matter of the crops varied little in the three soils, Cookeville, Crossville, and Gallatin, which averaged 93.11 grams of dry substance per gram of nitrogen. The crops from the Jackson soil, however, gave a ratio of 120.01 grams of dry substance per gram of nitrogen. A low nitrogen content was found to characterize alike the grain and the straw of the wheat, also the millet hay from the Jackson soil.

SOIL RESULTS

10. In every instance the cropped soils maintained a decidedly higher nitrogen content than the uncropped. This difference was noticeable both in the surface soil and in the first six inches of the subsoil, but the results from the 12-to-24-inch depth were inconclusive.

The losses of nitrogen from the surface soils under comparable conditions were as follows:

	Cropped	Uncropped
Cookeville	2.1 per cent	6.8 per cent
Crossville	1.2 per cent	6.2 per cent
Gallatin	12.4 per cent	18.2 per cent
Jackson	plus 0.4 per cent	4.2 per cent

11. The average combined saving in surface soil and subsoil nitrogen for the three most representative types, Cookeville, Crossville, and Gallatin, was 8.4 mgs per gram of air-dry crop, or 9.3 mgs per gram of dry substance harvested.

12. In uncropped experiments surface soil treated with ground limestone showed appreciable loss of nitrogen as compared with untreated. Under cropping, however, three of the four soils showed more nitrogen at the end of the five-year period in the limed cylinders than in the unlimed. This result is attributed to the offsetting of the direct loss through liming by the conservation of nitrogen brought about through increased crop production.

13. The effect of applications of acid phosphate and muriate of potash on the content of soil nitrogen was not appreciable under cropping. No experiments were made under uncropped conditions.

14. Where no crops were grown, top-dressings of nitrate of soda resulted in a small but evident loss of soil nitrogen.

Under cropping the nitrated cylinders showed a greater supply of both soil and subsoil nitrogen than the unnitrated, the difference being slight for the soil, but more pronounced for the subsoil. This result, as in the case of the ground limestone, is attributed to the more than balancing of the direct loss through nitrating by the conservation of nitrogen brought about through increased crop production.

15. Manure applied to the surface soil of uncropped cylinders did not increase the nitrogen content of the subsoil.

Under cropping the nitrogen content of the subsoils from the manured cylinders averaged somewhat higher than that from the unmanured; that is, manure applied to the surface soil conserved the supply of nitrogen in the subsoil.

16. If the loss of nitrogen from both the soil and subsoil be considered, the loss from the Cookeville, Crossville, and Gallatin soils was in each case greater than can be accounted for in the crops removed. In the case of the Jackson soil, however, this was not so, the subsoil showing a moderate loss but the surface soil of the cropped cylinders a slight gain.

17. The Jackson soil, which gave in many respects decidedly different results from any other, is noted as the only one to give evidence of the fixation of atmospheric nitrogen to a marked extent. To attribute this nitrogen accumulation to other exterior sources was considered untenable.

18. The general conclusion is drawn that not only the cropping, but also the manurial treatments conserved both the soil and the subsoil nitrogen to a total depth of about one foot, directly in proportion to the crop increase. This conservation does not, of course, prevent a loss of soil nitrogen through either chemical or biological processes induced per se by an applied substance such as ground limestone. In such a case the two opposing factors may or may not balance each other.

Since cover crops are often advocated because they catch soluble nitrogen that would otherwise be lost by leaching, attention may be called to the fact that the conservation referred to is not limited to the nitrogen utilized by the crops and conserved in the crop residues, but is an additional and actual conservation of soil nitrogen which may be utilized by farm crops.

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The writer takes pleasure in expressing his indebtedness to Dr. J. G. Lipman, Director of the New Jersey Agricultural Experiment Station, for valuable criticism of the plans at the outset of the experiments herein reported. The writer also wishes to express his appreciation of the assistance rendered by Dr. W. H. MacIntire, Mr. L. G. Willis, and Mr. J. I. Hardy, in making the major part of the nitrogen determinations on both soils and crops.

APPENDIX

TABLES

Tables VI, XIII, and XIV are, on account of their length, appended here in order not to interfere with the pages of the bulletin proper.

TABLE VI—*Yields of crops and their nitrogen content*

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
Cookeville	A1	L (1909)	1910	Oats	53.95	1.570	.8470
			1910	Millet	66.28	1.220	.8086
			1911	Wheat	46.88	1.100	.5157
			1911	Millet	79.43	0.910	.7228
			1912	Wheat	39.80	1.065	.4239
			1912	Millet	19.39	2.020	.3917
			1913	Wheat	24.13	0.914	.2205
			1913	Millet	35.50	1.510	.5361
			1914	Wheat	39.03	0.965	.3766
			1914	Millet	4.10	2.065	.0847
		Total			408.49		4.9276
Cookeville	A2	F (1909 & 1911)	1910	Oats	78.06	1.030	.8040
			1910	Millet	60.43	1.400	.8460
			1911	Wheat	47.67	1.220	.5816
			1911	Millet	88.34	0.770	.6802
			1912	Wheat	130.86	0.960	1.2563
			1912	Millet	12.71	1.695	.2154
			1913	Wheat	31.70	0.989	.3135
			1913	Millet	1.21	1.310	.0159
			1914	Wheat			
			1914	Millet			
		Total			450.98		4.7129
Cookeville	A3	L (1909)	1910	Oats	111.00	0.950	1.0545
		F (1909 & 1911)	1910	Millet	76.81	1.230	.9448

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1911	Wheat	65.01	0.970	.6306
			1911	Millet	115.01	0.720	.8281
			1912	Wheat	114.39	1.005	1.1496
			1912	Millet	94.68	1.013	.9591
			1913	Wheat	41.91	1.066	.4468
			1913	Millet	84.96	1.280	1.0875
			1914	Wheat	62.69	0.972	.6093
			1914	Millet	67.23	0.933	.6273
		Total			833.69		8.3376
Cookeville	A4	None	1910	Oats	25.30	1.590	.4023
			1910	Millet	27.02	1.500	.4053
			1911	Wheat	27.05	1.200	.3246
			1911	Millet	63.07	0.950	.5992
			1912	Wheat	3.21	1.152	.0370
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			145.65		1.7684
Cookeville	A5	L (1909)	1910	Oats	84.85	1.210	1.0267
		F (1909 & 1911)	1910	Millet	103.66	1.090	1.1299
		S (1909 & 1911)	1911	Wheat	68.23	0.970	.6618
			1911	Millet	138.40	0.690	.9550
			1912	Wheat	123.39	0.984	1.2142
			1912	Millet	119.55	0.833	.9959
			1913	Wheat	61.42	0.999	.6136
			1913	Millet	99.21	1.100	1.0913
			1914	Wheat	88.70	0.805	.7140
			1914	Millet	57.64	0.900	.5188
		Total			945.05		8.9212
Cookeville	A6	L (1909)	1910	Oats	94.90	1.150	1.0914
		F (1909 & 1911)	1910	Millet	95.86	1.330	1.2749
		S (1909 & 1911)	1911	Wheat	81.75	0.910	.7439

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		PK (annual)	1911	Millet	135.45	0.640	.8669
			1912	Wheat	122.86	0.965	1.1856
			1912	Millet	130.33	0.868	1.1313
			1913	Wheat	76.90	0.954	.7336
			1913	Millet	86.00	1.200	1.0320
			1914	Wheat	74.51	0.813	.6058
			1914	Millet	36.95	1.043	.3854
		Total			935.51		9.0508
Cookeville	A7	PK (annual)	1910	Oats	48.73	1.000	.4873
			1910	Millet	27.34	1.130	.3089
			1911	Wheat	45.57	1.040	.4739
			1911	Millet	55.20	0.870	.4802
			1912	Wheat	23.24	0.856	.1989
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			200.08		1.9492
Cookeville	A8	L (1909)	1910	Oats	75.05	1.080	.8105
		PK (annual)	1910	Millet	60.33	1.220	.7360
			1911	Wheat	55.61	0.980	.5450
			1911	Millet	97.93	0.740	.7247
			1912	Wheat	65.65	0.813	.5337
			1912	Millet	61.71	0.920	.5677
			1913	Wheat	55.95	1.147	.6417
			1913	Millet	53.20	1.200	.6384
			1914	Wheat	57.31	0.866	.4963
			1914	Millet	22.74	1.343	.3054
		Total			605.48		5.9994
Cookeville	A9	PK (annual)	1910	Oats	154.80	0.910	1.4087
		N (annual)	1910	Millet	43.56	1.180	.5140
			1911	Wheat	81.79	1.150	.9406
			1911	Millet	86.20	0.790	.6810

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1912	Wheat	38.67	0.872	.3372
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			405.02		3.8815
Cookeville	A10	L (1909)	1910	Oats	174.51	0.980	1.7102
		PK (annual)	1910	Millet	49.23	1.380	.6794
		N (annual)	1911	Wheat	97.66	1.050	1.0254
			1911	Millet	104.40	0.730	.7621
			1912	Wheat	112.25	0.797	.8946
			1912	Millet	41.52	1.073	.4455
			1913	Wheat	92.90	1.076	.9996
			1913	Millet	51.20	1.430	.7322
			1914	Wheat	94.74	1.255	1.1890
			1914	Millet	20.14	1.625	.3273
		Total			838.55		8.7653
Cookeville	B1	S (1909 & 1911)	1910	Oats	22.20	1.420	.3152
		PK (annual)	1910	Millet	44.74	1.190	.5324
			1911	Wheat	49.83	1.000	.4983
			1911	Millet	68.82	0.710	.4886
			1912	Wheat	21.55	0.842	.1815
			1912	Millet			
			1913	Wheat	1.75	0.560	.0098
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			208.89		2.0258
Cookeville	B2	L (1909)	1910	Oats	41.83	1.360	.5689
		S (1909 & 1911)	1910	Millet	90.53	1.100	.9958
		PK (annual)	1911	Wheat	60.00	0.930	.5580
			1911	Millet	110.20	0.630	.6943
			1912	Wheat	62.51	1.044	.6526

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1912	Millet	51.96	0.885	.4598
			1913	Wheat	56.08	0.914	.5126
			1913	Millet	66.55	1.030	.6855
			1914	Wheat	63.24	0.765	.4838
			1914	Millet	62.71	0.730	.4578
		Total			665.71		6.0691
Cookeville	B3	S (1909 & 1911)	1910	Oats	106.29	1.000	1.0629
		PK (annual)	1910	Millet	48.83	1.240	.6055
		N (annual)	1911	Wheat	65.67	1.220	.8012
			1911	Millet	99.55	0.760	.7566
			1912	Wheat	84.30	0.785	.6618
			1912	Millet			
			1913	Wheat	3.25	1.271	.0413
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			407.89		3.9293
Cookeville	B4	L (1909)	1910	Oats	130.23	0.870	1.1330
		S (1909 & 1911)	1910	Millet	53.70	1.180	.6337
		PK (annual)	1911	Wheat	117.36	1.020	1.1971
		N (annual)	1911	Millet	123.15	0.730	.8990
			1912	Wheat	144.71	0.704	1.0188
			1912	Millet	51.11	0.930	.4753
			1913	Wheat	125.46	0.960	1.2044
			1913	Millet	75.43	1.020	.7694
			1914	Wheat	95.69	1.170	1.1196
			1914	Millet	20.77	1.175	.2440
		Total			937.61		8.6943
Cookeville	B5	S (1909 & 1911)	1910	Oats	13.80	1.770	.2443
			1910	Millet	5.05	1.640	.0828
			1911	Wheat	43.23	1.010	.4366
			1911	Millet	65.14	0.760	.4951
			1912	Wheat	13.86	0.949	.1315
			1912	Millet			

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			141.08		1.3903
Cookeville	B6	L (1909)	1910	Oats	35.53	1.410	.5010
		S (1909 & 1911)	1910	Millet	76.34	1.290	.9848
			1911	Wheat	58.21	0.980	.5705
			1911	Millet	100.05	0.720	.7204
			1912	Wheat	33.68	1.142	.3846
			1912	Millet	36.88	1.330	.4905
			1913	Wheat	27.57	1.032	.2845
			1913	Millet	70.22	1.110	.7794
			1914	Wheat	48.17	0.930	.4480
			1914	Millet	27.11	1.013	.2746
		Total			513.76		5.4383
Cookeville	B7	L (1909)	1910	Oats	188.71	0.830	1.5663
		F (1909 & 1911)	1910	Millet	99.63	1.220	1.2155
		S (1909 & 1911)	1911	Wheat	101.08	0.980	.9906
		PK (annual)	1911	Millet	141.74	0.670	.9497
		N (annual)	1912	Wheat	214.72	0.882	1.8938
			1912	Millet	111.01	0.948	1.0524
			1913	Wheat	152.20	0.959	1.4596
			1913	Millet	64.11	1.220	.7821
			1914	Wheat	144.50	0.938	1.3554
			1914	Millet	25.44	1.345	.3422
		Total			1243.14		11.6076
Crossville	C1	L (1909)	1910	Oats	58.43	1.450	.8472
			1910	Millet	65.89	1.370	.9027
			1911	Wheat	41.24	1.190	.4908
			1911	Millet	65.65	1.100	.7222
			1912	Wheat	24.73	1.161	.2871
			1912	Millet	33.86	1.318	.4463
			1913	Wheat	35.51	0.488	.1733

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1913	Millet	26.51	1.400	.3711
			1914	Wheat	11.83	1.120	.1325
			1914	Millet	8.92	1.400	.1249
		Total			372.57		4.4981
Crossville	C2	F (1909 & 1911)	1910	Oats	95.78	1.100	1.0536
			1910	Millet	75.96	1.150	.8735
			1911	Wheat	19.92	1.260	.2510
			1911	Millet	94.55	0.900	.8510
			1912	Wheat	121.47	0.875	1.0629
			1912	Millet	45.71	1.345	.6148
			1913	Wheat			
			1913	Millet	1.04	1.170	.0122
			1914	Wheat			
			1914	Millet			
		Total			454.43		4.7190
Crossville	C3	L (1909)	1910	Oats	114.11	1.000	1.1411
		F (1909 & 1911)	1910	Millet	112.48	1.150	1.2935
			1911	Wheat	61.20	1.110	.6793
			1911	Millet	115.47	0.810	.9353
			1912	Wheat	120.35	0.935	1.1253
			1912	Millet	124.05	0.730	.9056
			1913	Wheat	43.18	1.066	.4603
			1913	Millet	108.31	1.000	1.0831
			1914	Wheat	60.63	0.953	.5778
			1914	Millet	47.76	1.015	.4848
		Total			907.54		8.6861
Crossville	C4	None	1910	Oats	29.03	1.620	.4703
			1910	Millet	14.15	1.650	.2335
			1911	Wheat			
			1911	Millet			
			1912	Wheat			
			1912	Millet			
			1913	Wheat			
			1913	Millet			

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1914	Wheat			
			1914	Millet			
		Total			43.18		.7038
Crossville	C5	L (1909)	1910	Oats	88.63	1.220	1.0813
		F (1909 & 1911)	1910	Millet	132.39	1.210	1.6019
		S (1909 & 1911)	1911	Wheat	65.41	0.940	.6149
			1911	Millet	119.30	0.770	.9186
			1912	Wheat	84.52	1.277	1.0793
			1912	Millet	143.95	0.800	1.1516
			1913	Wheat	50.38	0.949	.4781
			1913	Millet	104.37	1.030	1.0750
			1914	Wheat	56.48	0.888	.5015
			1914	Millet	37.27	1.100	.4100
		Total			882.70		8.9122
Crossville	C6	L (1909)	1910	Oats	101.53	1.150	1.1676
		F (1909 & 1911)	1910	Millet	137.40	1.150	1.5801
		S (1909 & 1911)	1911	Wheat	69.20	0.890	.6159
		PK (annual)	1911	Millet	127.39	0.600	.7643
			1912	Wheat	100.22	0.936	.9381
			1912	Millet	127.16	0.768	.9766
			1913	Wheat	55.30	0.956	.5287
			1913	Millet	129.76	0.890	1.1549
			1914	Wheat	77.00	0.862	.6637
			1914	Millet	78.90	1.050	.8285
		Total			1003.86		9.2184
Crossville	C7	PK (annual)	1910	Oats	53.48	1.120	.5990
			1910	Millet	36.84	1.380	.5084
			1911	Wheat			
			1911	Millet	13.43	1.570	.2109
			1912	Wheat	0.36	1.861	.0067
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1914	Millet			
		Total			104.11		1.3250
Crossville	C8	L (1909)	1910	Oats	85.25	1.020	.8696
		PK (annual)	1910	Millet	78.70	0.940	.7398
			1911	Wheat	48.48	1.100	.5333
			1911	Millet	99.08	0.750	.7431
			1912	Wheat	49.53	0.915	.4532
			1912	Millet	59.58	0.910	.5422
			1913	Wheat	34.74	0.978	.3398
			1913	Millet	57.70	1.040	.6001
			1914	Wheat	24.00	0.990	.2376
			1914	Millet	27.71	1.273	.3527
		Total			564.77		5.4114
Crossville	C9	PK (annual)	1910	Oats	137.39	1.310	1.7998
		N (annual)	1910	Millet	44.20	1.260	.5569
			1911	Wheat			
			1911	Millet	28.97	1.610	.4664
			1912	Wheat			
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			210.56		2.8231
Crossville	C10	L (1909)	1910	Oats	219.62	1.140	2.5037
		PK (annual)	1910	Millet	64.11	1.190	.7629
		N (annual)	1911	Wheat	85.40	1.090	.9309
			1911	Millet	131.15	0.720	.9443
			1912	Wheat	117.63	0.860	1.0116
			1912	Millet	68.30	0.808	.5519
			1913	Wheat	100.61	1.068	1.0745
			1913	Millet	55.98	1.150	.6438
			1914	Wheat	50.84	1.315	.6685
			1914	Millet	45.07	1.238	.5580
		Total			938.71		9.6501

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
Crossville	D1	S (1909 & 1911)	1910	Oats	44.44	1.450	.6444
		PK (annual)	1910	Millet	64.20	1.120	.7190
			1911	Wheat			
			1911	Millet	47.92	1.120	.5367
			1912	Wheat	8.95	1.165	.1043
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			165.51		2.0044
Crossville	D2	L (1909)	1910	Oats	54.57	1.240	.6767
		S (1909 & 1911)	1910	Millet	94.08	1.180	1.1101
		PK (annual)	1911	Wheat	63.49	0.910	.5778
			1911	Millet	100.84	0.820	.8269
			1912	Wheat	41.55	0.914	.3798
			1912	Millet	71.14	0.870	.6189
			1913	Wheat	23.33	1.034	.2412
			1913	Millet	94.38	1.000	.9438
			1914	Wheat	47.83	1.195	.5716
			1914	Millet	55.10	1.043	.5747
		Total			646.31		6.5215
Crossville	D3	S (1909 & 1911)	1910	Oats	104.17	1.150	1.1980
		PK (annual)	1910	Millet	53.43	1.150	.6144
		N (annual)	1911	Wheat	19.43	1.590	.3089
			1911	Millet	54.03	0.820	.4430
			1912	Wheat	6.14	1.103	.0687
			1912	Millet			
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			237.20		2.6330
Crossville	D4	L (1909)	1910	Oats	160.30	0.940	1.5068

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		S (1909 & 1911)	1910	Millet	84.97	0.980	.8327
		PK (annual)	1911	Wheat	111.44	1.050	1.1701
		N (annual)	1911	Millet	103.73	0.720	.7469
			1912	Wheat	123.43	0.833	1.0282
			1912	Millet	75.68	0.915	.6925
			1913	Wheat	120.60	0.924	1.1143
			1913	Millet	75.46	1.020	.7697
			1914	Wheat	62.74	1.213	.7610
			1914	Millet	62.70	1.005	.6301
		Total			981.05		9.2523
Crossville	D5	S (1909 & 1911)	1910	Oats	17.10	1.570	.2685
			1910	Millet	33.72	1.480	.4991
			1911	Wheat			
			1911	Millet	35.41	0.980	.3470
			1912	Wheat	5.30	0.975	.0517
			1912	Millet	1.69	1.505	.2543
			1913	Wheat			
			1913	Millet			
			1914	Wheat			
			1914	Millet			
		Total			93.22		1.4206
Crossville	D6	L (1909)	1910	Oats	41.71	1.390	.5798
		S (1909 & 1911)	1910	Millet	68.02	1.250	.8503
			1911	Wheat	47.41	1.070	.5073
			1911	Millet	91.27	0.790	.7210
			1912	Wheat	37.75	1.061	.4005
			1912	Millet	68.86	0.770	.5302
			1913	Wheat	24.96	1.158	.2890
			1913	Millet	63.56	1.060	.6737
			1914	Wheat	26.04	0.968	.2521
			1914	Millet	35.90	1.023	.3673
		Total			505.48		5.1712
Crossville	D7	L (1909)	1910	Oats	194.55	0.940	1.8288
		F (1909 & 1911)	1910	Millet	124.59	1.030	1.2833

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		S (1909 & 1911)	1911	Wheat	131.97	1.000	1.3197
		PK (annual)	1911	Millet	137.62	0.620	.8532
		N (annual)	1912	Wheat	202.91	0.817	1.6578
			1912	Millet	161.78	0.805	1.3023
			1913	Wheat	130.97	0.969	1.2694
			1913	Millet	122.48	0.880	1.0778
			1914	Wheat	138.86	0.949	1.3178
			1914	Millet	72.30	1.045	.7555
		Total			1418.03		12.6656
Gallatin	E1	L (1909)	1910	Oats	184.80	1.190	2.1991
			1910	Millet	84.34	1.040	.8771
			1911	Wheat	133.14	0.880	1.1716
			1911	Millet	108.76	0.710	.7722
			1912	Wheat	99.21	0.980	.9723
			1912	Millet	37.43	0.775	.2901
			1913	Wheat	89.83	0.875	.7860
			1913	Millet	73.00	1.080	.7884
			1914	Wheat	133.27	0.830	1.1061
			1914	Millet	3.20	1.625	.0520
		Total			946.98		9.0149
Gallatin	E2	F (1909)	1910	Oats	280.95	0.970	2.7252
			1910	Millet	110.96	0.970	1.0763
			1911	Wheat	160.64	0.940	1.5100
			1911	Millet	122.85	0.660	.8108
			1912	Wheat	252.09	0.852	2.1478
			1912	Millet	103.51	0.822	.8509
			1913	Wheat	152.03	0.860	1.3075
			1913	Millet	22.08	1.650	.3643
			1914	Wheat	163.10	0.940	1.5331
			1914	Millet			
		Total			1368.21		12.3259
Gallatin	E3	L (1909)	1910	Oats	267.03	1.160	3.0975
		F (1909 & 1911)	1910	Millet	125.68	0.930	1.1688
			1911	Wheat	195.32	1.110	2.1681

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1911	Millet	136.37	0.690	.9410
			1912	Wheat	253.73	0.939	2.3825
			1912	Millet	112.60	0.720	.8107
			1913	Wheat	97.14	0.934	.9073
			1913	Millet	122.25	1.010	1.2347
			1914	Wheat	171.68	0.805	1.3820
			1914	Millet			
		Total			1481.80		14.0926
Gallatin	E4	None	1910	Oats	171.00	0.970	1.6587
			1910	Millet	67.79	0.970	.6576
			1911	Wheat	99.27	0.940	.9331
			1911	Millet	112.57	0.640	.7204
			1912	Wheat	66.73	0.838	.5592
			1912	Millet	81.20	1.220	.9906
			1913	Wheat	19.74	0.793	.1565
			1913	Millet			
			1914	Wheat	12.75	1.693	.2159
			1914	Millet			
		Total			631.05		5.8920
Gallatin	E5	L (1909)	1910	Oats	213.87	1.050	2.2456
		F (1909 & 1911)	1910	Millet	121.00	1.080	1.3068
		S (1909 & 1911)	1911	Wheat	181.16	0.960	1.7391
			1911	Millet	140.88	0.670	.9439
			1912	Wheat	172.91	0.937	1.6202
			1912	Millet	161.32	0.660	1.0647
			1913	Wheat	101.50	0.973	.9876
			1913	Millet	125.58	0.920	1.1553
			1914	Wheat	182.33	0.793	1.4459
			1914	Millet	92.38	1.070	.9885
		Total			1492.93		13.4976
Gallatin	E6	L (1909)	1910	Oats	153.40	1.090	1.6721
		F (1909 & 1911)	1910	Millet	137.48	0.950	1.3061
		S (1909 & 1911)	1911	Wheat	146.82	1.020	1.4976
		PK (annual)	1911	Millet	112.60	0.730	.8220

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1912	Wheat	222.28	0.872	1.9383
			1912	Millet	151.74	0.643	.9757
			1913	Wheat	118.53	1.002	1.1877
			1913	Millet	128.69	0.930	1.1968
			1914	Wheat	179.21	0.788	1.4122
			1914	Millet	137.61	0.780	1.0734
		Total			1488.36		13.0819
Gallatin	E7	PK (annual)	1910	Oats	164.65	1.170	1.9264
			1910	Millet	58.76	1.000	.5876
			1911	Wheat	137.14	0.950	1.3028
			1911	Millet	116.98	0.650	.7604
			1912	Wheat	129.48	0.936	1.2119
			1912	Millet	16.69	1.088	.1816
			1913	Wheat	44.00	1.022	.4497
			1913	Millet	.49	1.670	.0082
			1914	Wheat	4.77	1.432	.0683
			1914	Millet			
		Total			672.96		6.4969
Gallatin	E8	L (1909)	1910	Oats	231.53	1.050	2.4311
		PK (annual)	1910	Millet	63.04	1.120	.7060
			1911	Wheat	98.22	0.950	.9331
			1911	Millet	112.85	0.660	.7448
			1912	Wheat	114.66	0.948	1.0870
			1912	Millet	61.24	0.723	.4428
			1913	Wheat	84.10	1.020	.8578
			1913	Millet	79.34	0.890	.7061
			1914	Wheat	130.26	0.798	1.0395
			1914	Millet	53.98	1.190	.6424
		Total			1029.22		9.5906
Gallatin	E9	PK (annual)	1910	Oats	308.06	1.150	3.5427
		N (annual)	1910	Millet	64.86	1.020	.6616
			1911	Wheat	213.12	0.860	1.8328
			1911	Millet	110.05	0.600	.6603
			1912	Wheat	232.38	0.739	1.7172

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1912	Millet	17.07	1.400	.2390
			1913	Wheat	83.74	1.148	.9613
			1913	Millet	.63	1.590	.0100
			1914	Wheat	174.50	1.264	2.2057
			1914	Millet			
		Total			1204.41		11.8306
Gallatin	E10	L (1909)	1910	Oats	359.24	1.230	4.4187
		PK (annual)	1910	Millet	76.63	1.150	.8812
		N (annual)	1911	Wheat	231.01	0.990	2.2870
			1911	Millet	138.23	0.590	.8156
			1912	Wheat	264.37	0.832	2.1996
			1912	Millet	48.48	0.788	.3820
			1913	Wheat	212.00	0.965	2.0458
			1913	Millet	70.74	1.080	.7640
			1914	Wheat	234.18	1.310	3.0678
			1914	Millet	27.64	1.633	.4514
		Total			1662.52		17.3131
Gallatin	F1	S (1909 & 1911)	1910	Oats	160.15	1.250	2.0019
		PK (annual)	1910	Millet	64.80	1.530	.9914
			1911	Wheat	103.48	0.870	9003
			1911	Millet	109.38	0.660	.7219
			1912	Wheat	81.89	0.881	.7215
			1912	Millet	56.46	0.845	.4771
			1913	Wheat	67.75	0.888	.6016
			1913	Millet	22.92	1.530	.3507
			1914	Wheat	184.97	0.825	1.5260
			1914	Millet			
		Total			851.80		8.2924
Gallatin	F2	L (1909)	1910	Oats	167.00	1.180	1.9706
		S (1909 & 1911)	1910	Millet	81.38	1.120	.9115
		PK (annual)	1911	Wheat	119.16	0.910	1.0844
			1911	Millet	122.00	0.670	.8174
			1912	Wheat	96.69	0.972	.9398
			1912	Millet	80.41	0.684	.5500

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1913	Wheat	60.53	0.999	.6047
			1913	Millet	100.75	0.860	.8665
			1914	Wheat	145.49	0.800	1.1639
			1914	Millet	100.99	0.808	.8160
		Total			1074.40		9.7248
Gallatin	F3	S (1909 & 1911)	1910	Oats	298.36	0.990	2.9538
		PK (annual)	1910	Millet	70.05	1.080	.7565
		N (annual)	1911	Wheat	230.65	0.810	1.8683
			1911	Millet	104.72	0.730	.7645
			1912	Wheat	219.30	0.761	1.6689
			1912	Millet	57.64	0.835	.4813
			1913	Wheat	128.72	0.967	1.2447
			1913	Millet	22.04	1.560	.3438
			1914	Wheat	261.63	1.010	2.6425
			1914	Millet			
		Total			1393.11		12.7243
Gallatin	F4	L (1909)	1910	Oats	281.37	0.960	2.7011
		S (1909 & 1911)	1910	Millet	95.95	1.040	.9979
		PK (annual)	1911	Wheat	233.17	0.940	2.1918
		N (annual)	1911	Millet	126.82	0.680	.8624
			1912	Wheat	224.05	0.805	1.8036
			1912	Millet	98.47	0.713	.7021
			1913	Wheat	163.50	0.875	1.4306
			1913	Millet	100.69	0.850	.8559
			1914	Wheat	250.79	1.053	2.6408
			1914	Millet	68.49	1.375	.9417
		Total			1643.30		15.1279
Gallatin	F5	S (1909 & 1911)	1910	Oats	103.47	1.400	1.4486
			1910	Millet	33.77	1.870	.6315
			1911	Wheat	179.00	0.940	1.6826
			1911	Millet	123.90	0.630	.7806
			1912	Wheat	81.64	0.848	.6923
			1912	Millet	51.99	0.830	.4315
			1913	Wheat	54.65	0.839	.4585

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1913	Millet	0.74	1.570	.0116
			1914	Wheat	123.63	0.873	1.0793
			1914	Millet			
		Total			752.79		7.2165
Gallatin	F6	L (1909)	1910	Oats	169.37	1.120	1.8969
		S (1909 & 1911)	1910	Millet	98.77	1.050	1.0371
			1911	Wheat	152.87	1.010	1.5440
			1911	Millet	107.95	0.710	.7664
			1912	Wheat	93.81	0.970	.9100
			1912	Millet	107.56	0.705	.7583
			1913	Wheat	41.49	0.972	.4033
			1913	Millet	110.90	0.930	1.0314
			1914	Wheat	140.33	0.798	1.1198
			1914	Millet	29.45	1.563	.4603
		Total			1052.50		9.9275
Gallatin	F7	L (1909)	1910	Oats	340.88	1.210	4.1246
		F (1909 & 1911)	1910	Millet	126.91	1.000	1.2691
		S (1909 & 1911)	1911	Wheat	354.33	1.040	3.6850
		PK (annual)	1911	Millet	159.28	0.630	1.0035
		N (annual)	1912	Wheat	324.16	0.998	3.2351
			1912	Millet	161.16	0.790	1.2732
			1913	Wheat	161.56	1.062	1.7158
			1913	Millet	128.64	0.960	1.2349
			1914	Wheat	331.40	0.853	2.8268
			1914	Millet	29.95	1.990	.5960
		Total			2118.27		20.9640
Jackson	G1	L (1909)	1910	Oats	109.17	0.840	.9170
			1910	Millet	54.12	1.160	.6278
			1911	Wheat	69.22	0.800	.5538
			1911	Millet	81.08	0.660	.5351
			1912	Wheat	117.10	0.725	.8490
			1912	Millet	68.49	0.783	.5363
			1913	Wheat	84.90	0.789	.6699
			1913	Millet	80.50	0.620	.4991

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1914	Wheat	96.41	0.735	.7086
			1914	Millet	85.78	0.653	.5601
		Total			846.77		6.4567
Jackson	G2	F (1909 & 1911)	1910	Oats	159.70	0.870	1.3894
			1910	Millet	76.09	1.130	.8598
			1911	Wheat	90.16	0.780	.7032
			1911	Millet	90.88	0.610	.5544
			1912	Wheat	202.46	0.686	1.3889
			1912	Millet	108.12	0.750	.8109
			1913	Wheat	55.39	1.040	.5761
			1913	Millet	115.03	0.630	.7247
			1914	Wheat	89.37	0.775	.6926
			1914	Millet	94.60	0.700	.6622
		Total			1081.80		8.3622
Jackson	G3	L (1909)	1910	Oats	177.56	0.780	1.3850
		F (1909 & 1911)	1910	Millet	67.60	1.150	.7774
			1911	Wheat	87.66	0.700	.6136
			1911	Millet	84.75	0.620	.5255
			1912	Wheat	201.72	0.707	1.4262
			1912	Millet	108.65	0.738	.8018
			1913	Wheat	68.02	0.995	.6768
			1913	Millet	111.84	0.660	.7381
			1914	Wheat	89.07	0.833	.7420
			1914	Millet	123.18	0.570	.7021
		Total			1120.05		8.3885
Jackson	G4	None	1910	Oats	99.69	0.770	.7676
			1910	Millet	41.12	1.250	.5140
			1911	Wheat	72.40	0.790	.5720
			1911	Millet	76.42	0.560	.4280
			1912	Wheat	83.28	0.692	.5757
			1912	Millet	42.12	0.800	.3370
			1913	Wheat	43.62	0.843	.3677
			1913	Millet	32.06	1.000	.3206
			1914	Wheat	74.21	0.703	.5217

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
			1914	Millet	15.27	1.685	.2573
		Total			580.19		4.6616
Jackson	G5	L (1909)	1910	Oats	132.05	0.800	1.0564
		F (1909 & 1911)	1910	Millet	87.21	1.040	90.70
		S (1909 & 1911)	1911	Wheat	93.88	0.720	.6759
			1911	Millet	99.19	0.660	.6547
			1912	Wheat	168.79	0.794	1.3402
			1912	Millet	120.50	0.745	.8977
			1913	Wheat	115.91	0.849	.9841
			1913	Millet	117.08	0.640	.7493
			1914	Wheat	112.75	0.805	.9076
			1914	Millet	108.85	0.670	.7293
		Total			1156.21		8.9030
Jackson	G6	L (1909)	1910	Oats	125.67	0.950	1.1939
		F (1909 & 1911)	1910	Millet	88.88	1.010	.8977
		S (1909 & 1911)	1911	Wheat	103.97	0.760	.7902
		PK (annual)	1911	Millet	92.88	0.660	.6130
			1912	Wheat	172.16	0.807	1.3893
			1912	Millet	130.84	0.710	.9290
			1913	Wheat	79.74	0.875	.6977
			1913	Millet	127.76	0.630	.8049
			1914	Wheat	100.93	0.800	.8074
			1914	Millet	140.65	0.543	.7637
		Total			1163.48		8.8868
Jackson	G7	PK (annual)	1910	Oats	148.33	0.700	1.0383
			1910	Millet	42.77	1.220	.5218
			1911	Wheat	79.01	0.720	.5689
			1911	Millet	62.86	0.670	.4212
			1912	Wheat	100.30	0.698	.7001
			1912	Millet	31.20	0.783	.2443
			1913	Wheat	37.97	0.839	.3186
			1913	Millet	72.69	0.650	.4725
			1914	Wheat	65.28	0.785	.5124
			1914	Millet	52.76	0.885	.4669
		Total			693.17		5.2650

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
Jackson	G8	L (1909)	1910	Oats	116.68	0.740	.8634
		PK (annual)	1910	Millet	59.29	1.050	.6225
			1911	Wheat	63.12	0.860	.5428
			1911	Millet	81.64	0.660	.5388
			1912	Wheat	109.81	0.724	.7950
			1912	Millet	74.78	0.773	.5780
			1913	Wheat	80.97	0.822	.6657
			1913	Millet	74.05	0.600	.4443
			1914	Wheat	87.83	0.738	.6482
			1914	Millet	99.50	0.613	.6099
		Total			847.67		6.3086
Jackson	G9	PK (annual)	1910	Oats	280.11	0.680	1.9047
		N (annual)	1910	Millet	39.80	1.230	.4895
			1911	Wheat	180.50	0.810	1.4621
			1911	Millet	78.82	0.620	.4887
			1912	Wheat	234.50	0.597	1.4000
			1912	Millet	57.50	0.793	.4560
			1913	Wheat	167.03	0.689	1.1509
			1913	Millet	57.04	0.800	.4563
			1914	Wheat	167.60	0.810	1.3576
			1914	Millet	55.97	0.778	.4354
		Total			1318.87		9.6012
Jackson	G10	L (1909)	1910	Oats	291.70	0.770	2.2461
		PK (annual)	1910	Millet	60.84	1.080	.6571
		N (annual)	1911	Wheat	156.31	0.690	1.0785
			1911	Millet	75.05	0.700	.5254
			1912	Wheat	248.19	0.614	1.5239
			1912	Millet	57.68	0.837	.4829
			1913	Wheat	177.45	0.766	1.3593
			1913	Millet	73.58	0.640	.4709
			1914	Wheat	170.47	0.858	1.4626
			1914	Millet	104.53	0.615	.6429
		Total			1415.80		10.4496
Jackson	H1	S (1909 & 1911)	1910	Oats	118.56	0.830	.9840

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		PK (annual)	1910	Millet	8.35	1.050	.0877
			1911	Wheat	86.07	0.730	.6283
			1911	Millet	92.23	0.630	.5810
			1912	Wheat	78.52	0.831	.6525
			1912	Millet	62.30	0.813	.5065
			1913	Wheat	50.97	1.021	.5204
			1913	Millet	85.04	0.620	.5272
			1914	Wheat	73.80	0.800	.5904
			1914	Millet	83.43	0.720	.6007
		Total			739.27		5.6787
Jackson	H2	L (1909)	1910	Oats	140.62	0.810	1.1390
		S (1909 & 1911)	1910	Millet	72.92	1.120	.8167
		PK (annual)	1911	Wheat	91.30	0.690	.6300
			1911	Millet	90.50	0.630	.5702
			1912	Wheat	87.21	0.827	.7212
			1912	Millet	80.31	0.768	.6168
			1913	Wheat	72.70	0.944	.6863
			1913	Millet	90.59	0.650	.5888
			1914	Wheat	97.24	0.763	.7419
			1914	Millet	109.20	0.585	.6388
		Total			932.59		7.1497
Jackson	H3	S (1909 & 1911)	1910	Oats	298.74	0.660	1.9717
		PK (annual)	1910	Millet	61.62	1.010	.6224
		N (annual)	1911	Wheat	200.86	0.680	1.3658
			1911	Millet	62.36	0.770	.4802
			1912	Wheat	193.48	0.659	1.2750
			1912	Millet	73.95	0.778	.5753
			1913	Wheat	169.64	0.755	1.2808
			1913	Millet	84.23	0.640	.5391
			1914	Wheat	154.47	0.955	1.4752
			1914	Millet	109.74	0.610	.6694
		Total			1409.09		10.2549
Jackson	H4	L (1909)	1910	Oats	268.40	0.670	1.7982
		S (1909 & 1911)	1910	Millet	66.15	1.120	.7409

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		PK (annual)	1911	Wheat	197.44	0.720	1.4216
		N (annual)	1911	Millet	81.30	0.640	.5203
			1912	Wheat	215.33	0.643	1.3846
			1912	Millet	77.68	0.768	.5966
			1913	Wheat	174.95	0.879	1.5378
			1913	Millet	92.13	0.630	.5804
			1914	Wheat	202.80	0.810	1.6427
			1914	Millet	121.95	0.600	.7317
		Total			1498.13		10.9548
Jackson	H5	S (1909 & 1911)	1910	Oats	145.38	0.800	1.1630
			1910	Millet	71.48	1.000	.7148
			1911	Wheat	81.95	0.750	.6146
			1911	Millet	92.35	0.630	.5818
			1912	Wheat	79.92	0.774	.6186
			1912	Millet	60.91	0.768	.4678
			1913	Wheat	44.02	0.977	.4301
			1913	Millet	90.75	0.700	.6353
			1914	Wheat	73.10	0.825	.6031
			1914	Millet	80.95	0.735	.5950
		Total			820.81		6.4241
Jackson	H6	L (1909)	1910	Oats	135.29	0.750	1.0147
		S (1909 & 1911)	1910	Millet	80.74	1.040	.8397
			1911	Wheat	89.92	0.740	.6654
			1911	Millet	95.85	0.660	.6326
			1912	Wheat	94.81	0,822	.7793
			1912	Millet	82.19	0.810	.6657
			1913	Wheat	75.38	0.977	.7365
			1913	Millet	113.98	0.660	.7523
			1914	Wheat	106.40	0.750	.7980
			1914	Millet	113.28	0.628	.7114
		Total			987.84		7.5956
Jackson	H7	L (1909)	1910	Oats	317.33	0.730	2.3165
		F (1909 & 1911)	1910	Millet	108.91	1.000	1.0891
		S (1909 & 1911)	1911	Wheat	226.31	0.740	1.6747

TABLE VI (*Continued*)

SOIL	Cylinder No.	Treatment	Year of harvest	Crop	Yield of air-dry subs. per cylinder	Nitrogen content	Total nitrogen in crop
					Grams	Per cent	Grams
		PK (annual)	1911	Millet	106.30	0.640	.6803
		N (annual)	1912	Wheat	312.04	0.686	2.1406
			1912	Millet	147.25	0.685	1.0087
			1913	Wheat	221.03	0.800	1.7682
			1913	Millet	123.68	0.730	.9029
			1914	Wheat	226.98	0.793	1.7999
			1914	Millet	164.41	0.575	.9454
		Total			1954.24		14.3263
Jackson	I8	D (1909)	1910	Oats	194.00	0.810	1.5714
		F (1909 & 1911)	1910	Millet	102.41	1.090	1.1163
		S (1909 & 1911)	1911	Wheat	122.07	0.750	.9155
		PK (annual)	1911	Millet	118.15	0.640	.7562
			1912	Wheat	177.16	0.808	1.4315
			1912	Millet	90.32	0.913	.8246
			1913	Wheat	128.95	0.860	1.1090
			1913	Millet	143.92	0.680	.9787
			1914	Wheat	117.77	0.735	.8656
			1914	Millet	154.60	0.540	.8348
		Total			1349.35		10.4036

TABLE XIII—*The nitrogen content of the surface soils at different periods. Estimations calculated to moisture-free basis*

SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent
"Average" samples of untreated soils taken in 1909, at the outset of the experiments									
Cookeville	1096	-----	-----------	0.0742	Gallatin	1267	-----	-----------	0.1463
Crossville	1101	-----	-----------	0.0784	Jackson	1266	-----	-----------	0.0593

TABLE XIII (*Continued*)

SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent
Samples taken in 1911, at the end of the two-year period									
Cookeville	1874	A 1	L	0.0745	Crossville	1911	8	LPK	0.0727
"	1875	2	F	0.0751	"	1912	9	LFPK	0.0768
"	1876	3	LF	0.0805	"	1913	10	LSPK	0.0762
"	1877	4	O	0.0760	"	1967	J 4	LSFPK	0.0794
"	1878	5	LSF	0.0846	"	1968	5	LPKN	0.0731
"	1879	6	LSFPK	0.0854	"	1969	6	LSPKN	0.0763
"	1880	7	PK	0.0738	Gallatin	1914	E 1	L	0.1264
"	1881	8	LPK	0.0710	"	1915	2	F	0.1346
"	1882	9	PKN	0.0797	"	1916	3	LF	0.1347
"	1883	10	LPKN	0.0720	"	1917	4	O	0.1294
"	1884	B 1	SPK	0.0740	"	1918	5	LSF	0.1364
"	1885	2	LSPK	0.0723	"	1919	6	LSFPK	0.1381
"	1886	3	SPKN	0.0782	"	1920	7	PK	0.1376
"	1887	4	LSPKN	0.0747	"	1921	8	LPK	0.1304
"	1888	5	S	0.0760	"	1922	9	PKN	0.1311
"	1889	6	LS	0.0760	"	1923	10	LPKN	0.1297
"	1890	7	LSFPKN	0.0823	"	1924	F 1	SPK	0.1320
"	1891	8	LPK	0.0698	"	1925	2	LSPK	0.1306
"	1892	9	LFPK	0.0752	"	1926	3	SPKN	0.1306
"	1893	10	LSPK	0.0695	"	1927	4	LSPKN	0.1318
"	1964	J 1	LSFPK	0.0740	"	1928	5	S	0.1306
"	1965	2	LPKN	0.0664	"	1929	6	LS	0.1348
"	1966	3	LSPKN	0.0699	"	1930	7	LSFPKN	0.1393
Crossville	1894	C 1	L	0.0817	"	1931	8	LPK	0.1247
"	1895	2	F	0.0897	"	1932	9	LFPK	0.1318
"	1896	3	LF	0.0874	"	1933	10	LSPK	0.1291
"	1897	4	O	0.0817	"	1970	J 7	LSFPK	0.1350
"	1898	5	LSF	0.0868	"	1971	8	LPKN	0.1247
"	1899	6	LSFPK	0.0848	"	1972	9	LSPKN	0.1298
"	1900	7	PK	0.0788	Jackson	1934	G 1	L	0.0620
"	1901	8	LPK	0.0759	"	1935	2	F	0.0674
"	1902	9	PKN	0.0774	"	1936	3	LF	0.0656
"	1903	10	LPKN	0.0776	"	1937	4	O	0.0568
"	1904	D 1	SPK	0.0871	"	1938	5	LSF	0.0725
"	1905	2	LSPK	0.0835	"	1939	6	LSFPK	0.0664
"	1906	3	SPKN	0.0869	"	1940	7	PK	0.0568
"	1907	4	LSPKN	0.0837	"	1941	8	LPK	0.0569
"	1908	5	S	0.0815	"	1942	9	PKN	0.0561
"	1909	6	LS	0.0800	"	1943	10	LPKN	0.0572
"	1910	7	LSFPKN	0.0860	"	1944	H 1	SPK	0.0598

TABLE XIII (*Continued*)

SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent
Jackson	1945	2	LSPK	0.0649	Jackson	1955	2	L	0.0544
"	1946	3	SPKN	0.0626	"	1956	3	PK	0.0525
"	1947	4	LSPKN	0.0631	"	1957	4	SFPK	0.0654
"	1948	5	S	0.0624	"	1958	5	SF	0.0654
"	1949	6	LS	0.0610	"	1959	6	LSF	0.0643
"	1950	7	LSFPKN	0.0694	"	1960	7	FeSF	0.0644
"	1951	8	LPK	0.0524	"	1961	8	LSFPK	0.0718
"	1952	9	LFPK	0.0586	"	1962	9	LPKN	0.0557
"	1953	10	LSPK	0.0567	"	1963	10	LSPKN	0.0569
"	1954	I 1	O	0.0562	"	1973	J10	LSFPK	0.0648

Samples taken in 1914, at the end of the five-year period

SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent
Cookeville	3799	A 1	L	0.0684	Crossville	3825	7	PK	0.0742
"	3800	2	F	0.0759	"	3826	8	LPK	0.0737
"	3801	3	LF	0.0795	"	3827	9	PKN	0.0762
"	3802	4	O	0.0741	"	3828	10	LPKN	0.0763
"	3803	5	LSF	0.0828	"	3829	D 1	SPK	0.0838
"	3804	6	LSFPK	0.0896	"	3830	2	LSPK	0.0845
"	3805	7	PK	0.0709	"	3831	3	SPKN	0.0824
"	3806	8	LPK	0.0724	"	3832	4	LSPKN	0.0846
"	3807	9	PKN	0.0714	"	3833	5	S	0.0821
"	3808	10	LPKN	0.0724	"	3834	6	LS	0.0783
"	3809	B 1	SPK	0.0731	"	3835	7	LSFPKN	0.0911
"	3810	2	LSPK	0.0711	"	3836	8	LPK	0.0704
"	3811	3	SPKN	0.0755	"	3837	9	LFPK	0.0763
"	3812	4	LSPKN	0.0740	"	3838	10	LSPK	0.0707
"	3813	5	S	0.0746	"	3892	J 4	LSFPK	0.0784
"	3814	6	LS	0.0726	"	3893	5	LPKN	0.0693
"	3815	7	LSFPKN	0.0838	"	3894	6	LSPKN	0.0739
"	3816	8	LPK	0.0646	Gallatin	3839	E 1	L	0.1184
"	3817	9	LFPK	0.0750	"	3840	2	F	0.1290
"	3818	10	LSPK	0.0681	"	3841	3	LF	0.1325
"	3889	J 1	LSFPK	0.0749	"	3842	4	O	0.1217
"	3890	2	LPKN	0.0619	"	3843	5	LSF	0.1394
"	3891	3	LSPKN	0.0658	"	3844	6	LSFPK	0.1367
Crossville	3819	C 1	L	0.0796	"	3845	7	PK	0.1219
"	3820	2	F	0.0904	"	3846	8	LPK	0.1245
"	3821	3	LF	0.0943	"	3847	9	PKN	0.1281
"	3822	4	O	0.0820	"	3848	10	LPKN	0.1270
"	3823	5	LSF	0.0915	"	3849	F 1	SPK	0.1272
"	3824	6	LSFPK	0.0904	"	3850	2	LSPK	0.1247

TABLE XIII (*Continued*)

SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Treatment	Total nitrogen Per cent
Gallatin	3851	3	SPKN	0.1251	Jackson	3869	H 1	SPK	0.0625
"	3852	4	LSPKN	0.1283	"	3870	2	LSPK	0.0672
"	3853	5	S	0.1242	"	3871	3	SPKN	0.0625
"	3854	6	LS	0.1290	"	3872	4	LSPKN	0.0670
"	3855	7	LSFPKN	0.1283	"	3873	5	S	0.0598
"	3856	8	LPK	0.1146	"	3874	6	LS	0.0689
"	3857	9	LFPK	0.1211	"	3875	7	LSFPKN	0.0791
"	3858	10	LSPK	0.1201	"	3876	8	LPK	0.0539
"	3895	J 7	LSFPK	0.1228	"	3877	9	LFPK	0.0610
"	3896	8	LPKN	0.1123	"	3878	10	LSPK	0.0560
"	3897	9	LSPKN	0.1157	"	3879	I 1	O	0.0544
Jackson	3859	G 1	L	0.0615	"	3880	2	L	0.0534
"	3860	2	F	0.0669	"	3881	3	PK	0.0524
"	3861	3	LF	0.0711	"	3882	4	SFPK	0.0645
"	3862	4	O	0.0555	"	3883	5	SF	0.0688
"	3863	5	LSF	0.0739	"	3884	6	LSF	0.0635
"	3864	6	LSFPK	0.0739	"	3885	7	FeSF	0.0689
"	3865	7	PK	0.0565	"	3887	9	LPKN	0.0542
"	3866	8	LPK	0.0603	"	3888	10	LSPKN	0.0564
"	3867	9	PKN	0.0595	"	3898	J10	LSFPK	0.0640
"	3868	10	LPKN	0.0617					

TABLE XIV—*The nitrogen content of the subsoils at different periods. Estimations calculated to moisture-free basis*

SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent
"Average" samples of "6-to-12-inch" subsoils taken in 1908, at time of placing in cylinders									
Cookeville	1097	-----	-----------	0.0300	Gallatin	----	-----	-----------	------
Crossville	1107	-----	-----------	0.0607	Jackson	1280	-----	-----------	0.0324
Samples of "6-to-12-inch" subsoils, taken in 1914									
Cookeville	3899	A 1	L	0.0261	Cookeville	3902	4	O	0.0261
"	3900	2	F	0.0274	"	3903	5	LSF	0.0270
"	3901	3	LF	0.0274	"	3904	6	LSFPK	0.0277

TABLE XIV (*Continued*)

SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent
"	3905	7	PK	0.0265	Gallatin	3940	2	F	0.0770
"	3906	8	LPK	0.0307	"	3941	3	LF	0.0735
"	3907	9	PKN	0.0276	"	3942	4	O	0.0681
"	3908	10	LPKN	0.0274	"	3943	5	LSF	0.0768
"	3909	B 1	SPK	0.0275	"	3944	6	LSFPK	0.0736
"	3910	2	LSPK	0.0266	"	3945	7	PK	0.0691
"	3911	3	SPKN	0.0269	"	3946	8	LPK	0.0702
"	3912	4	LSPKN	0.0289	"	3947	9	PKN	0.0775
"	3913	5	S	0.0259	"	3948	10	LPKN	0.0752
"	3914	6	LS	0.0256	"	3949	F 1	SPK	0.0746
"	3915	7	LSFPKN	0.0272	"	3950	2	LSPK	0.0750
"	3916	8	LPK	0.0234	"	3951	3	SPKN	0.0743
"	3917	9	LFPK	0.0267	"	3952	4	LSPKN	0.0740
"	3918	10	LSPK	0.0257	"	3953	5	S	0.0719
"	3989	J 1	LSFPK	0.0274	"	3954	6	LS	0.0733
"	3990	2	LPKN	0.0262	"	3955	7	LSFPKN	0.0723
"	3991	3	LSPKN	0.0274	"	3956	8	LPK	0.0684
Crossville	3919	C 1	L	0.0569	"	3957	9	LFPK	0.0699
"	3920	2	F	0.0578	"	3958	10	LSPK	0.0697
"	3921	3	LF	0.0610	"	3995	J 7	LSFPK	0.0698
"	3922	4	O	0.0571	"	3996	8	LPKN	0.0605
"	3923	5	LSF	0.0589	"	3997	9	LSPKN	0.0624
"	3924	6	LSFPK	0.0609	Jackson	3959	G 1	L	0.0286
"	3925	7	PK	0.0608	"	3960	2	F	0.0284
"	3926	8	LPK	0.0444	"	3961	3	LF	0.0274
"	3927	9	PKN	0.0563	"	3962	4	O	0.0254
"	3928	10	LPKN	0.0604	"	3963	5	LSF	0.0297
"	3929	D 1	SPK	0.0548	"	3964	6	LSFPK	0.0274
"	3930	2	LSPK	0.0576	"	3965	7	PK	0.0285
"	3931	3	SPKN	0.0584	"	3966	8	LPK	0.0282
"	3932	4	LSPKN	0.0595	"	3967	9	PKN	0.0287
"	3933	5	S	0.0564	"	3968	10	LPKN	0.0317
"	3934	6	LS	0.0526	"	3969	H 1	SPK	0.0299
"	3935	7	LSFPKN	0.0574	"	3970	2	LSPK	0.0306
"	3936	8	LPK	0.0593	"	3971	3	SPKN	0.0311
"	3937	9	LFPK	0.0576	"	3972	4	LSPKN	0.0306
"	3938	10	LSPK	0.0528	"	3973	5	S	0.0306
"	3992	J 4	LSFPK	0.0563	"	3974	6	LS	0.0329
"	3993	5	LPKN	0.0542	"	3975	7	LSFPKN	0.0339
"	3994	6	LSPKN	0.0562	"	3976	8	LPK	0.0292
Gallatin	3939	E 1	L	0.0684	"	3977	9	LFPK	0.0292

TABLE XIV (*Continued*)

SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent	SOIL	Lab. No.	Cyl. No.	Surface-soil treatment	Total nitrogen Per cent
Jackson	3978	10	LSPK	0.0297	Jackson	3984	6	LSF	0.0319
"	3979	I 1	O	0.0312	"	3985	7	FeSF	0.0327
"	3980	2	L	0.0318	"	3986	8	LSFPK	0.0347
"	3981	3	PK	0.0312	"	3987	9	LPKN	0.0319
"	3982	4	SFPK	0.0323	"	3988	10	LSPKN	0.0324
"	3983	5	SF	0.0312	"	3998	J10	LSFPK	0.0327

Agricultural Experiment Station

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BULLETIN NO. 119 DECEMBER, 1917

GROUND LIMESTONE AND PROSPERITY ON THE FARM

BY

C. A. MOOERS

CLOVER HAY FROM EXPERIMENTAL PLOTS, KNOX COUNTY

LIMED UNLIMED
WITH FERTILIZER

LIMED UNLIMED
WITHOUT FERTILIZER

KNOXVILLE, TENNESSEE

The Agricultural Experiment Station
OF THE UNIVERSITY OF TENNESSEE

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The Experiment Station building, containing the offices and laboratories, and the plant house, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farms, the barns, stables, dairy building, etc., are located one mile west of the University, on the Kingston Pike. The fruit farm is adjacent to the Industrial School, and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

GROUND LIMESTONE AND PROSPERITY ON THE FARM

INTRODUCTORY

For the past twelve years the Tennessee Agricultural Experiment Station has conducted experiments in all parts of the State to determine the value of liming. In these experiments a wide variety of crops has been used, from legumes with high lime requirements, such as alfalfa, to non-legumes, with low lime requirements, such as cotton and sweet potatoes. In addition, the effects of liming on the nitrogen and humus contents of the soil have been carefully investigated. The purpose has been to find out not only the immediate value of liming in crop production for the various soils, but also the final effect on the soil itself. This was especially important in view of the widespread belief that liming, though profitable for a time, results in a loss of soil fertility. The evidence obtained has shown both that liming is generally profitable in all divisions of the State, and that, at least so far as ground limestone is concerned, there need be no fear of harmful after-effects, but that on the contrary a permanent increase in fertility is to be expected.*

Since a large part of the experimental work has been done with ground limestone, the use of this material applied at the rate of 2 tons per acre may be assumed by the reader, unless otherwise specified.

The writer wishes to place especial emphasis upon the fact that throughout the bulletin the aim is to give a true impression of the value of liming under practical conditions. The results are believed to be representative of the various soils and crops, and not in any sense exceptional in nature.

* See Bulletin 118, pp. 147 and 148.

RESULTS OF FIELD EXPERIMENTS

LIMING VERY BENEFICIAL TO ALFALFA AND THE CLOVERS

The effect of liming on alfalfa has been especially marked. In fact, the getting of a profitable crop without liming is so unusual as to attract attention. This exceptional case is found in all parts of the State, but is generally limited to a small area, and may not prove a trustworthy indication for the surrounding district. In five series of experiments, on representative soils in different sections of the State, the average yield with lime was 3.13 tons per acre of cured hay, but without lime only 1.16 tons. These results were obtained the first season after seeding. As a rule the unlimed alfalfa is more or less smothered out the second year by crab grass, whereas the limed alfalfa is then at its best.

Red and alsike clovers are very sensitive to a deficiency of lime, though not to the same extent as alfalfa. In eleven series of experiments the average yield of clover hay on common soils of East, Middle, and West Tennessee was 2.31 tons per acre with lime, but only 1.48 tons, mixed with weeds, where no lime was used.

White clover, so far as the writer's observation goes, can be classed with red and alsike in lime requirement. Crimson clover, on the other hand, may be benefited by liming, but responds less than any other kind.

LIMING FOR CORN, WHEAT AND OTHER GRAINS

Numerous experiments have been made to determine the effects of liming on both corn and wheat under common farm conditions. The results show a marked and rather uniform increase in yield from liming. In twelve series the average yield of corn was 36.5 bushels per acre where limed, but where unlimed, the average was only 30.8 bushels. Some of the experiments were carried out for several years, and the favorable effects continued from year to year. At the Ford farm, in Knox County, plots which received 6 tons of manure every other year gave, in eight years of continuous cropping in corn, a total yield of 279 bushels per acre. In the same period, and under the same conditions, except that an application of 2 tons per acre of ground limestone was made at the outset, adjoining plots produced 350 bushels per acre, or a gain of 71 bushels. At 75 cents per bushel, the value of the increase was $53.00 for the eight-year period. At the present war price of $1.25 per bushel the value of the increase would be $88.75. In this case the increased yield was above the average, but the writer wishes to emphasize the fact that

the good effects of liming are not limited to the first year or two after the application.

The actual increase in bushels per acre for wheat on limed land is not so great as for corn, but the percentage increase is about the same. Seventeen series of experiments conducted on various types of soil show an average yield of 16.8 bushels per acre on the limed plots, and 14.0 bushels on the unlimed, or an increase of 20 per cent due to liming. Of course the fertilizers used and the time of seeding were the same in each case; that is, every precaution was taken in these, as in all the experiments cited, to make the conditions the same except as to the one condition of lime as compared with no lime.

LIMING FOR FORAGE CROPS AND GRASSES

Both forage crops and grasses have been included in the experiments. The average yield of thirteen series with soy beans was 1.78 tons of cured hay per acre under liming, and 1.45 tons without lime. The average of eight series with cowpeas was 1.13 tons of hay per acre under liming, and 0.85 ton without lime. Both of these crops have shown a ready response to liming. In fact, land that will produce them equally well whether limed or unlimed is exceptional, and is limited chiefly to the most fertile soils. This exception naturally applies also to other crops, such as corn, wheat and grass.

Experiments with the common cultivated grasses, such as orchard, tall oat, Kentucky blue grass, timothy, and red top, have been made in different parts of the State. The results have shown that the first four grasses usually respond to liming, which may even be essential to their successful culture. Red top, however, may thrive without liming where the others fail.

LIMING FOR GARDEN CROPS

A plentiful supply of lime is important to most garden crops, among which beets, lettuce and asparagus may be mentioned in particular. Tomatoes and peppers have been moderately helped by liming in our experiments, while watermelons, sweet potatoes, and a few other crops appear indifferent to such treatment. It should be mentioned that the long-continued and heavy manuring practiced by many gardeners would be expected to take the place of liming so as to render it in most instances unnecessary for garden crops.

THE DURATION OF THE EFFECT OF LIMING

The effect of even a moderate liming lasts for a number of years. In our experiments appreciable increases in crop yields from a single application have continued for at least eight years. At the West Tennessee Station, at Jackson, in a five-year general-farm rotation a single application of 2 tons per acre of ground limestone gave, in the next eight years, the following increases:

Crops	Increase per acre from one liming	Value per unit	Calculated value of increase
2 crops of cowpea hay..........	0.92 ton	$12.00	$11.04
2 crops of wheat................	6.10 bu.	1.00	6.10
2 crops of clover hay............	2.29 tons	12.00	27.48
1 crop of cotton. ....46.00 lbs. (seed cotton)			2.50
1 crop of corn..................	6.10 bu.	.75	4.58

Total value of increase for eight years, as compared with adjoining unlimed plots..............................$51.70

At present war prices the total value of the increase would amount to over $75.00.

At the Knoxville Station the increased yields from a single application of burnt lime, applied at the rate of 1 ton per acre, resulted in the following increases during the course of the next ten years:

Crops	Increase per acre from one liming	Value per unit	Calculated value of increase
2 crops of corn	4.90 bu.	$ .75	$ 3.68
2 crops of wheat	2.00 bu.	1.00	2.00
2 crops of clover and grass.......	1.50 tons	12.00	18.00
2 crops of soy-bean hay..........	0.28 tons	12.00	3.36

Total value of increase for ten years, as compared with adjoining unlimed plots $27.04

In connection with the latter series it should be noted that moderate and equivalent applications of farmyard manure and commercial fertilizers were made both to the limed and unlimed areas. The soil was a fertile brown-colored loam. Even under these conditions, which were favorable to good crops without liming, liming proved highly profitable and the effects were evident throughout the ten years.

THE IMPORTANCE OF LIMING IN SOIL UPBUILDING

To build up a soil poor in lime without the aid of liming is an especially difficult task for several reasons. One reason is that the greatest of all soil-improvement crops, red clover, cannot be satisfactorily grown where lime is deficient. With the aid of ground limestone, clover would be found to flourish on farms where it has long been a stranger. On many other farms where clover now makes but meager growth or is lacking somewhat in color and thrift, liming would cause it to grow luxuriantly. Grasses of all kinds grown with clover do better the second year than those grown without clover, and a good grass sod means a mellow, friable soil, capable of producing a first-class corn crop. It has already been shown that liming increases nearly all farm crops. This means that larger residues of vegetable matter are left in the soil and that as a result soil fertility is conserved for the crops that follow. There is one precaution neces-

sary, however, and that is that we bear in mind the fact that liming does not take the place of either phosphate or potash, so that a soil deficient in one or both of these fertilizer elements should have the deficiency supplied the same as if no lime were used. On the other hand, liming increases the soil supply of available nitrogen, especially by increasing the growth of legumes, as the experimental data amply show. If the leguminous crops be either pastured off or made into hay which is fed on the farm, and the manure saved and returned to the land, the increase in fertility should be very material.

NEED OF LIME FOR VARIOUS TYPES OF TENNESSEE SOILS

INDICATIONS OF THE NEED OF LIMING

The growth of red clover is perhaps as good an indication as any of the need of lime. If this crop cannot be grown satisfactorily, producing from 2 to 3 tons of cured hay per acre, when aided by fertilizer and a light dressing of manure, the need of liming is strongly indicated. So accustomed are many farmers to a soil poor in lime that they do not seem to realize that a 2-to-3-ton crop can be expected on a well-limed soil of fair fertility. "Sour dock" and "poor Joe" are common weeds on soils needing lime. Through liming they are largely crowded out, and become less noticeable. A light green color in either cowpeas or soy beans generally means lime deficiency.

SOIL TESTS

Of the soil tests that are sometimes advocated, the old litmus test seems about the most reliable. If the blue litmus paper when dipped into a paste of soil and pure water soon turns red, the need of lime is indicated.

SOILS OF EAST TENNESSEE

The soils of East Tennessee are chiefly of limestone origin. Even the shale, or slate, which produces the so-called slaty soils, contains an appreciable quantity of lime. East Tennessee soils, however, regardless of origin, analyze poor in lime, practically no carbonate, the form found in the limestone rock, being present. However, there is a difference in the extent to which the different soils respond to liming. In general the brown or chocolate-colored soils need lime less than either the gray or the yellowish-colored soils. It is a common occurrence in the experimental work to find long-cultivated soils which at one time produced excellent crops of red clover but which now require liming in order to make this crop a success. In fact, it may be assumed for practically all uplands long in cultivation and much depleted in fertility, or "worn out," that liming will prove highly beneficial.

SOILS OF THE CUMBERLAND PLATEAU

The soils of the Cumberland Plateau are especially poor in lime, so that liming is profitable from the outset on the newly cleared land. It should be considered one of the first essentials to the successful farming of this promising section.

SOILS OF THE HIGHLAND RIM

Generally speaking, the Highland Rim soils are in need of liming. Even on the best of the brown, or mulatto-colored, soils, such as are found in Franklin County, it has been amply demonstrated that liming is required in order to produce alfalfa successfully. Also soils of this type which at one time yielded excellent crops of red clover

TALL OAT GRASS AND RED CLOVER ON LIMED LAND AT CLARKSVILLE TOBACCO STATION—LANE UNSUITED TO CLOVER WITHOUT LIME

are now often found to require lime in order to make clover a success. The gray lands of the Barrens type are naturally very poor in lime, which has repeatedly been found, in the Station's experiments, to be helpful to practically all crops.

SOILS OF THE CENTRAL BASIN

The soils of the Central Basin are less apt to require liming than are those of any other large area in the State. However, numerous trials have convinced the writer that liming will prove profitable on the majority of the uplands in the Basin. Not only is the seeding of alfalfa on unlimed land rarely advisable, but as a rule, in our cooperative experiments, the yield of red clover has been materially increased by liming. Recent experiments at various points

on the red-colored soils of Rutherford County have uniformly shown an increased yield of soy beans under liming, with indications that other crops will respond in a similar manner.

SOILS OF WEST TENNESSEE

The soils of West Tennessee, though not of limestone origin, except along the eastern border, are about as well supplied with lime as are the average soils in the other portions of the State. In certain places, such as the rich alluvial lands of Lake County and the rich lowlands of Obion County, alfalfa is grown successfully without the aid of liming. If, however, the soils at the Jackson Station be taken as representative of West Tennessee, liming is fundamentally im-

RED CLOVER AND TALL OAT GRASS ON LIMED LAND AT JACKSON STATION —YIELD 3 TONS CURED HAY PER ACRE LAND UNSUITED TO CLOVER WITHOUT LIME

portant. At that Station liming proved essential to the getting of both alfalfa and clover, and greatly increased all the common crops, with the possible exception of cotton. Even the growth of Japan clover was found to be appreciably increased by liming. Recent experiments conducted by the Station on the demonstration farm of the Nashville, Chattanooga & St. Louis Railway at Martin confirm the results obtained over a period of nine years at Jackson.

THE HOME-GRINDING OF LIMESTONE

GENERAL CONSIDERATIONS

Since limestone of good quality is well distributed over both East and Middle Tennessee, and is also found along the eastern border of West Tennessee, the matter of grinding it either on the farm or within easy hauling distance has aroused considerable interest among the farmers. Undoubtedly local grinding is the best practice wherever the freight or the distance from the nearest railroad siding makes the cost of transported material excessive. On the other hand, proximity to a mine or quarry which produces ground rock as a by-product, may make home-grinding uneconomical.

A number of firms are manufacturing small portable limestone grinders which do excellent work. The prices of these small machines vary at present from $260.00 to $750.00, or more. Naturally the higher-priced machines possess advantages over the lower-priced. The latter may, however, be used to advantage in some instances because of their low first cost, especially if only a moderate acreage is to be limed.

The cost of home-grinding varies considerably—according to reports received, from 75 cents to $1.50 per ton. In many instances, however, little or no allowance has been made in the estimate for interest on the investment and wear and tear of machinery.

FINENESS OF GRINDING

The best degree of fineness to which the rock may be ground in practice has not been determined. About all the guide we have is the practical guess or opinion of those who have had experience and have given thought to the matter. At present the Station is advising that the rock need be ground no finer than will pass through a ¼-inch-mesh screen; that is, the coarsest particles may be in the neighborhood of ¼ inch in size and the rest from that to "flour." A fair condition for ground limestone is as follows:

Size of sieve	Per cent retained
20-mesh*	26
40 "	28
60 "	12
80 "	6
100 "	3
Total	75

* This refers to a sieve having 20 square openings to the linear inch.

This leaves 25 per cent of material fine enough to pass through a 100-mesh sieve.

As demonstrated in our rate-of-liming experiments, a 2-ton application of high-grade limestone of this grinding has proved ample for alfalfa, which seems to have the highest lime requirement of all

farm crops. There is no doubt that the finer the particles the greater is the immediate efficiency. On the other hand, the coarse particles, while being slowly reduced in size, will remain longer in the soil than the finer ones, and a heavy application will do away with the necessity of frequent though light applications of a flour-like material, which can be obtained, though at greatly increased cost. Some practical farmers even prefer to make an extremely heavy application, of 15 tons or more to the acre, of a coarsely but cheaply ground rock with a view to liming only once in a lifetime.

QUALITY OR GRADE OF ROCK

Although some variation is found in the quality, or degree of purity of Tennessee limestones, a rock of good grade (90 per cent or more) is within the reach of nearly every community in the limestone sections of the State. Low-grade rock is apt to be undesirable, not only because of increased cost in grinding—estimated by one company manufacturing grinders as 1 cent per ton increase in wear and tear of machinery for each 1 per cent of impurity—but also because of less ready solubility in the soil and the increased application which the low grade necessitates. However, conditions may be present which justify the use of a rock of very low grade. Since the grade of a rock is not always known and cannot be told by inspection, the safe plan is to have it analyzed before grinding. This is especially advisable in a section like East Tennessee, where choice may be had of several kinds of rock within easy hauling distance.

THE VALUE OF DOLOMITE

Since dolomite, or magnesian limestone, is a common formation in East Tennessee, the question as to its value for liming purposes is important. This Station has made some field experiments with dolomite furnished by the American Ballast Co. The product averages about 50 per cent calcium carbonate and 38 per cent magnesium carbonate. In these experiments, which were made with alfalfa on a soil much in need of lime, the dolomite gave fully as good results as the high-grade marble used for comparison. In experiments made at other stations dolomite appears to have been nearly or quite the equal of the common calcium limestone. There appears therefore no reason why dolomite should not be recommended.

OTHER FORMS OF LIME THAT MAY BE USED

Burnt lime, or its close relative, hydrated lime, and wood ashes, have been used extensively in liming. The latter material contains some readily soluble potash, to which popular impression attributes almost its whole worth. However, it is valuable on Tennessee soils largely because of its lime content, which varies from 25 to 40 per cent and is, roughly, equal to twice these amounts of ground limestone.

A few years ago "liming" meant applying burnt lime. One ton of this material is practically equal to two tons of ground limestone, but if immediate availability be considered it must be rated much higher than that. Burnt lime is expensive and troublesome to apply, and a heavy application may result in some waste of soil organic matter, including nitrogen. Under some circumstances its use may be advisable, but the ground rock, on account of its keeping qualities and ease of handling, as well as its cheapness and efficiency, has nearly everywhere displaced the burnt lime.

Hydrated lime is made by treating burnt lime with steam. The product contains about 22½ per cent of combined water, but is in a fine powdery condition, which fits it for immediate use on the lawn, garden or field. It is practically the same thing as burnt lime so far as effects on crops and soil are concerned.

HOW AND WHEN TO APPLY GROUND LIMESTONE

Several makes of distributors which handle ground limestone are on the market, and though none is beyond criticism, their use is advisable under general farm conditions; that is, they reduce the labor and make a more even distribution than can be got otherwise. The manure spreader may be used, but is not considered equal to the special distributor. Ground rock can, however, be satisfactorily spread by hand, so that the small farmer need not buy a distributor. Perhaps the best plan is to throw out the limestone in small heaps and then scatter it. This method helps to get a definite quantity to the acre and is an aid to even distribution. Forty-pound heaps 21 feet each way make 2 tons per acre.

Ground limestone may be applied at any season of the year, and for any crop, to suit the convenience of the worker. The main thing is to get it on the land. It is, of course, especially desirable previous to clover rather than to cotton, for example. To insure full benefit, the application should be well mixed with the soil. A good plan is to apply to unplowed ground, disc well into the soil, and follow with the turn plow.

CONCLUSION

After diligent study for many years the writer has reached the conclusion that even under conditions which existed prior to the war liming offered more immediate and greater rewards to the Tennessee farmer than any other simple resource at his command. Under present war conditions this possibility has been greatly increased, and full advantage of it should unhesitatingly be taken.

Agricultural Experiment Station

OF THE

University of Tennessee

BULLETIN NO. 120 JULY, 1918

THE HOG LOUSE

BY

H. R. WATTS

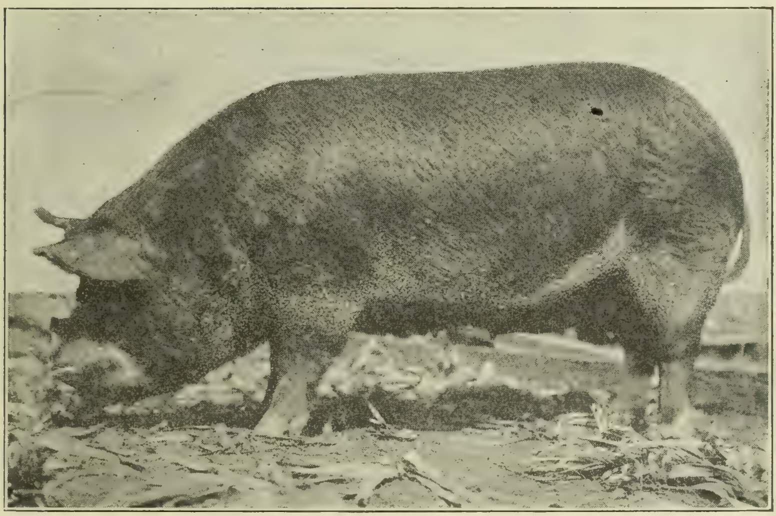

FIG. 1. BAND OF EGGS ON LOWER PARTS OF THE BODY OF A HOG
The eggs are represented by white dots

KNOXVILLE, TENNESSEE

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OF THE UNIVERSITY OF TENNESSEE

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The Experiment Station building, containing the offices and laboratories, and the plant house, are located on the University campus, 15 minutes' walk from the Custom House in Knoxville. The experiment farms, the barns, stables, dairy building, etc., are located about one mile west of the University, on the Kingston Pike. The fruit farm is adjacent to the Industrial School, and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

THE HOG LOUSE

Haematopinus suis (Linnaeus) Leach

BY

H. R. WATTS

INTRODUCTION

This bulletin is a preliminary report and a popular account of the results of the investigations of the life-history and habits of the hog louse carried on at the Experiment Station at Knoxville. These results are published at this time (1) to meet a rapidly increasing demand for accurate knowledge of the life-history and habits of this common parasite, concerning which comparatively little has heretofore been known; (2) to correct misunderstandings regarding some phases of its habits; and (3) to make suggestions for its control and eradication. Work was actively begun in November, 1914, and has been carried on continuously since that time. Thousands of lice and eggs have been carefully studied under natural conditions and on different breeds of hogs.

So far as is consistent with a good understanding of the life-history and habits of the pest, the more minute details and facts which do not seem to apply in the majority of cases under average natural conditions are omitted for the sake of brevity. A more detailed and technical account, including a description of the methods employed in arriving at the facts upon which this bulletin is based, is left for a later publication.

THE FULL-GROWN, OR ADULT, LOUSE

The hog louse is the largest louse* affecting farm animals. The full-grown female is about one-fifth of an inch long, and the male a little smaller, about one-sixth of an inch long. The color is gray or grayish brown, with definite brown and black markings. As commonly found on the hog, the louse is of a dirty, or dusty-gray, color closely resembling that of the skin of the host animal. This is due to the dust that collects on the louse. If the tip of the finger be lightly passed over the body the dust is rubbed off and the natural color appears.

*Note—Ticks are not classified as lice, and hence are not included here. The body of a louse is divided into three distinct parts, and has only six legs when full-grown. The body of a tick is divided into only two distinct parts; it has six legs when young, but eight when full-grown.

The body is divided into three parts, head, thorax, and abdomen, which are easily distinguished. (Figs. 2 and 3). The head is long and slender, and rounded at the front end. The mouth is located on the anterior end of the head and is provided with tiny, sharp, needle-like parts with which the louse pierces the skin of the hog and sucks the blood, very much as does the mosquito. These parts are very small

FIG. 2. FULL-GROWN FEMALE
Twenty times natural size

and can be seen only with the aid of a microscope. They are kept drawn into the head except when the louse is feeding.

The louse, like all other insects, has six legs attached to the underside of the thorax, or second part of the body. The thorax is shorter than the head, but much broader. The legs are long and stout, light yellow in color, and marked with several black areas. Each foot is provided with one long, curved, pointed claw, one short

"claw," and between these a small, flat pad. (Fig. 4). The feet are thus especially adapted for clasping and holding the hairs, or bristles, of the host. The long claw clasps a hair and draws it tightly against the pad, while the short claw assists in keeping it in place. This may be better understood if one closes the last three fingers of the hand, places the thumb against the second joint of the second finger, and then firmly clasps a pencil with the index finger. The index finger corresponds to the long claw, the thumb to the short claw, and the folded second finger to the pad. The louse is thus able to

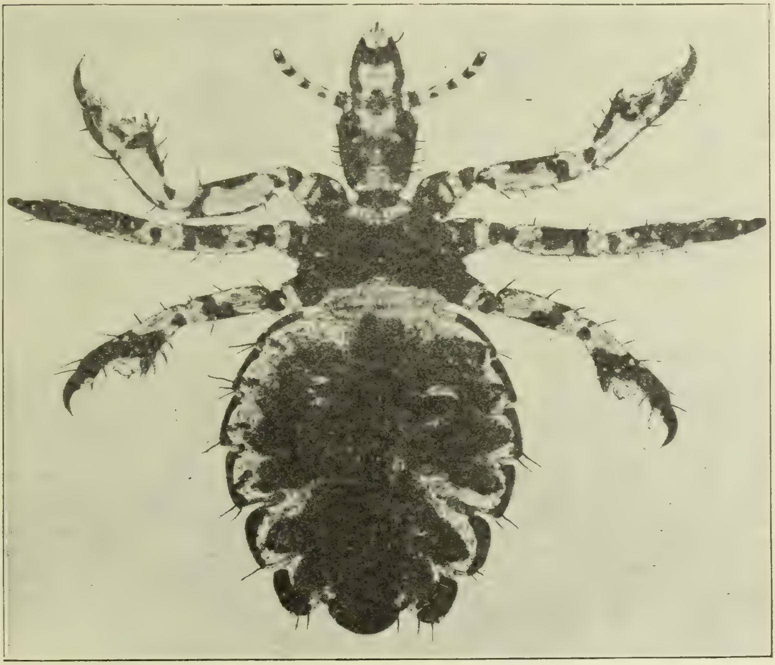

FIG. 3. FULL-GROWN MALE

Twenty times natural size

hold so firmly that it is with difficulty removed from the host. It can cling to the host while the latter rubs against fences, barns, or other objects. The long, sharp claw is also used in crawling on the skin between the hairs, or where the hairs are scattered. This does not hurt the host.

The third and largest part of the body is the abdomen, which is about one-half the total length of the louse. It is composed of several sections, or segments, its margin being notched, or wavy, and bordered with dark-colored lines, which are plainly visible. The full-grown male and female are easily distinguished by the abdomen. That of

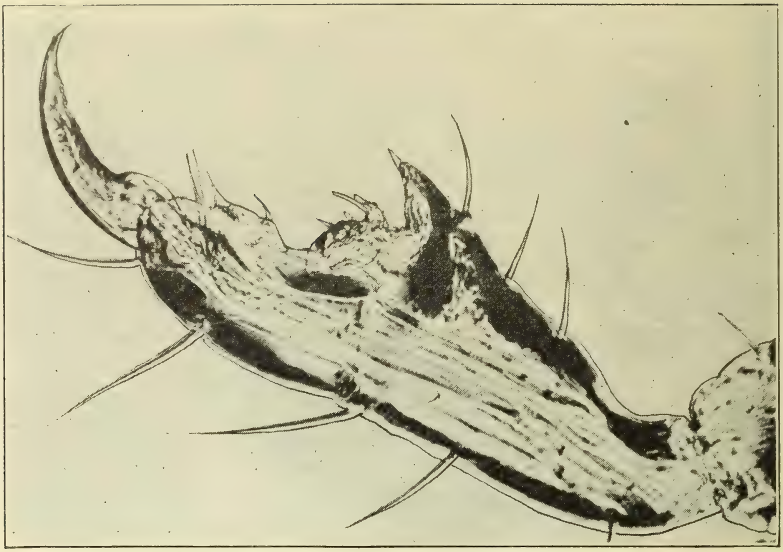

FIG. 4. FOOT
One hundred times natural size

the male is nearly round, while that of the female, besides being much larger, is broad near the forepart, and tapers to the rear, so that it has a somewhat pointed appearance. The last, or end, segment of the male is round and smooth and of a brownish color, while that of the female is black, with a light-colored, V-shaped opening at the rear. (Figs. 2 and 3). The underside of the abdomen of the male has a black streak in the middle of the last three segments which is not found in the female. (Fig. 5).

FIG. 5. BLACK STREAK ON UNDERSIDE OF ABDOMEN OF FULL-GROWN MALE
Twenty times natural size

THE EGGS, OR "NITS"

Upon examining lousy hogs one finds a large number of "nits," attached to the base of the hairs, especially on certain parts of the body. These nits are eggs (Fig. 6) laid by the full-grown female lice.

The eggs are white when first laid and remain this color indefinitely unless stained by mud, manure, or other dirt, when they become a yellowish or brownish color. Upon examining hogs kept under the usual conditions one often finds many of the eggs to be of some shade of brown or yellow, due to the unclean quarters of the animals. Even under these conditions, however, some white eggs can usually be found among the stained ones. These are generally the eggs laid after the others were stained. The eggs are long and oval, one end being much larger than the other. At the larger end they are bluntly rounded, just behind this they are a little wider, then taper to the smaller end. They are about one-twentieth of an inch long, and one-fiftieth of an inch wide, or about two and one-half

FIG. 6. EGG, SHOWING MANNER IN WHICH IT IS GLUED TO THE HAIR

Twenty times natural size

times as long as wide. On the larger end is a round cap which may not be noticed at first, but if examined under a hand lens can be clearly seen. The cap is the same color as the rest of the shell, and is distinguished by a fine line running around the end. When an egg hatches, the young louse pushes the cap off and comes out through the hole, which is almost as large as the entire end of the egg.

The eggs are attached to the base of the hairs, and while they may be found on almost any part of the host, the majority are found on well-defined areas, which form a broad band running chiefly around the lower parts of the body, including the sides of the neck, the lines of meeting hairs between the neck and the jowl, the breast, arms, and foreflanks, the lines of meeting hairs between the sides and belly, the rear flanks, hocks and twist. (Fig. 1). They are also commonly found, in smaller numbers, on the jowl, shields, lower halves of the sides, and the lower halves of the hams; but only in limited numbers on the upper parts of the body, including the face, ears, top of

neck, tops of shoulders, back, loins, hip and rump. They are rarely, if ever, found on the shanks and tail.

From the foregoing it will be seen that most of the eggs are laid on the lower half of the body and above the shanks. This is an important point to remember when applying any method for the eradication or control of the pest, because the eggs can be killed as easily as the lice, and by the same treatment.

The eggs hatch within from thirteen to twenty days after they are laid. They begin hatching on the thirteenth day, only a few hatching at this time; the number rapidly increases until and including the sixteenth day, then rapidly decreases until the end of the twentieth day. Under the average natural conditions about fifty per cent of the eggs hatch on the fifteenth, sixteenth and seventeenth days. This fact is important because it indicates how often treatment should be made. Under some conditions a few of the eggs hatch slightly earlier or later, but the number is so small that it is of little or no practical importance.

FIG. 7. YOUNG LOUSE, ONE DAY OLD
Twenty times natural size

THE YOUNG LOUSE

The newly hatched louse is about three sixty-fourths of an inch in length and is practically the same shape as the full-grown louse. It is pale yellow, with brownish mouth parts and claws. On account of its light color and small size the young louse may easily be overlooked on the body of the hog.

The young louse becomes very active as soon as it is hatched, and begins crawling over the skin of the host searching for a suitable place to feed. It prefers the thin, soft skin found about the ears, sides of the neck, jowl, breast, inside of the legs, lower sides, and belly. When a suitable place is found the louse inserts its tiny, sharp mouth parts and sucks the blood in a manner similar to that of the mosquito. It feeds rapidly and within a few minutes becomes well filled with blood, which is easily seen inside its body and appears as

a bright red spot in the middle of the abdomen. When the louse is first hatched its abdomen is rather short and wrinkled, but as it feeds this becomes longer and smoother, due to the quantity of blood it has sucked.

The hog louse does not engorge itself, as is the habit of ticks, but feeds frequently. It grows rapidly and soon changes from the pale yellow, or almost whitish, color to a light brownish-yellow, and then to a much darker, or brownish, color. It then sheds its skin, or molts, after which it is larger and about the same color as when newly hatched. It soon changes back, however, to the darker, or brownish, color. This process continues as the louse grows, the color being very light just after each molt and quickly changing to the dark color, which remains until the next molt. Upon examining hogs closely one may find several of these light-colored, newly-molted, young lice of various sizes and ages.

EGG-LAYING

The lice begin mating in from ten to twelve days after hatching and the female begins laying eggs when from eleven to thirteen days old; in other words, about as soon as she becomes full-grown. Each egg is glued to the base of a hair and is laid so that the smaller end practically touches the skin of the host, which keeps the egg warm until it hatches, several days later. The larger end of the egg, which contains the cap, points away from the body; that is, toward the free end of the hair.

The female deposits only one egg at a time, and the entire operation requires but a few seconds, so that one seldom sees a female lay an egg unless watching closely for some time. She usually lays three or four eggs a day, but sometimes as many as five. On hogs that have only a few lice the females seldom lay more than one egg on a hair; but on badly infested animals they lay several eggs on a single hair, on the lower parts of the body, rather than go to other parts where no eggs have been laid. The author has found as many as twenty-six eggs on a single hair on the lower parts of the body of a badly infested hog, while nearly all of the hairs on the upper parts of the body of the same animal were without any eggs. It is probable that thirty or more eggs could be found on a single hair of a moderately large hog which is badly infested. This again shows the importance of treating the lower parts of the body of an infested animal as thoroughly as the upper parts in order to kill the eggs.

The eggs can be slipped along the hairs, and are often pulled away from the body by the rubbing of the animals, or are pushed away by the growth of the hairs. This leaves the base of the hairs again free from eggs, and as the older ones are moved away from the body others are laid in their places, so that eggs are often found closely packed from the base to the end of the hairs. In these cases

the eggs next to the body are the newly laid ones, while those toward the end of the hairs are the oldest, the majority of which have hatched. Many of the eggs are rubbed to the end of the hairs, where they finally drop to the ground.

DURATION OF LIFE

Under natural conditions many lice are injured, killed, or lost from the host before they live their full life. Those remaining usually live from fifteen to twenty days after becoming full-grown. The total length of life under natural conditions is about thirty days. A few lice have been found to attain the age of over forty days, but this is exceptional. There are from six to fifteen generations a year, the usual number being from nine to twelve.

HABITS

Young lice are frequently found clustered on the inside of the ears of the host, often deep in the inner canal; in the folds of the neck; on the inside of the legs, close to the body; and in other protected places. This condition becomes especially noticeable with the approach of cold weather in the fall, and continues throughout the fall and winter. It is most common when the animals are separated or running in large lots or open fields. It also prevails, however, on hogs lying in contact, and under these conditions, in cold weather, lice are often found clustered on the lower parts of the body, where they are protected from the cold and where feeding conditions seem to be ideal. Occasionally they are found clustered on the animals in warm weather. The older lice also frequently seek the warmer parts of the body in cold weather, but do not, as a rule, cluster to the same extent as the younger ones. In many cases both young and old are found in the same cluster.

Lice of all ages are commonly found under the scurf, or scales, of the skin, where, in winter, they are protected from the cold air and kept warm by the skin beneath. This condition is common, however, in summer as well as winter, especially on the upper parts of the body, apparently because the lice find it necessary to get into contact with the newer skin to feed.

When the hog louse desires food it seeks a suitable place on the skin, inserts its sharp mouth parts, and sucks the blood. It does not feed on the scales of the skin or on the hair, as is the case with some other lice. When the mouth parts are first inserted they produce a sharp, stinging sensation, which irritates the animal and frequently gives considerable pain, causing it to rub the affected spot against fences, barns, or other convenient objects.

Hogs which have had thorough treatment so as to kill every louse and egg, and are then kept free from the parasites, do but little rubbing. On the other hand, if even a small number of lice are

placed on these same animals they soon begin frequent, and in many cases violent, rubbing, and often within a few days they will have rubbed the dirt and scales off the skin in large areas, which become inflamed. Lice torment the animals by "biting" them and the animals aggravate the irritation by the frequent and violent rubbing, which makes the skin much more tender and more susceptible to attacks. Lousy hogs often rub to such an extent that the skin is scratched or torn in small places and the blood seeps out. Lice collect in large numbers around such bleeding wounds, and apparently feed in the margin. Fifty or more lice may often be found closely packed around a single wound. This condition frequently exists even on hogs that are only "moderately lousy."

Lousy hogs, while they may not become noticeably poor, cannot be expected to do as well as hogs that are given the proper treatment and kept free from lice. There are two reasons for this: First, the lice feed frequently and suck large quantities of blood which otherwise would go to the building up of the bodies of the hogs. This loss of blood also results in a waste of feed. Second, the continual biting worries the hogs and makes them restless. It is reasonable to expect that hogs which are kept free from this tormenting pest will grow faster than lousy hogs.

The question is often asked whether hogs do not become sufficiently accustomed to lice not to be greatly annoyed and thus deterred in growth. The fact is, so long as hogs remain lousy the skin remains irritated, and as soon as treatment is given and the lice are killed the hogs begin to do better. But even if they are not annoyed by the lice, the saving of the loss of blood would well repay the cost of treatment.

It is commonly believed that large numbers of lice crawl off the hogs and secrete themselves in the bedding and the cracks of the barns or in other hiding places about the animals' quarters, and in this way spread from pen to pen. But the author's investigations at this Station do not show this to be the case. Lice may crawl off the animals to the bedding materials, especially if the animals are badly infested, but this must be regarded as accidental and not the rule.

The author has repeatedly rid hogs of all lice and eggs and kept them for several weeks in the same barn with lousy hogs, sometimes in adjoining pens, without their becoming reinfested. The clean hogs were carefully examined every day or two without a single louse or egg being found on them.

In all of these experiments, double partitions, with walls about twelve inches apart, were used between the pens; but they were made of ordinary rough boards with both small and large cracks between them, so that the lice might easily have crawled through. Sometimes bedding was allowed to accumulate between the walls of the partitions and the hogs lay against each side of the partitions,

but not a single louse crawled from the lousy animals on one side to the clean animals on the other. These hogs were allowed to run out into adjoining pens separated by double fences which had wire on one side of the posts and boards on the other side. The wire and boards were about six inches apart. The object of the double partitions and fences was to prevent the hogs in one pen from coming into contact with those in the adjoining pens.

In other experiments, where lousy hogs were allowed to come into contact with clean hogs, lice were found to crawl from the lousy to the clean animals within a few days. Again, a lousy hog was placed in the same pen with one or more animals which were free from lice and eggs and it was found that the lice crawled from the lousy hog to the clean ones so rapidly that in a few days the previously clean animals were as badly infested as the other.

Lice also have been found to crawl onto the hands, and sometimes the clothing, of persons handling lousy hogs, and by this means a few lice may be spread to other animals handled soon afterward. Thus man becomes a temporary host, and the lice occasionally bite him; but they do not remain long on the human body or on clothing. The hog louse apparently can not live except on the body of the hog. Therefore, no precautionary measures with reference to other animals need be taken. The hog louse normally spends its entire life and lays its eggs on the body of the hog.

In addition to the results of the above experiments, there are five other reasons for believing that the hog louse does not generally infest barns or pens.

First, its feet, as above described, are especially adapted for grasping and holding the hairs, or bristles, of hogs and not for crawling about bedding, floors, and walls, although the louse can, with difficulty, crawl over straw or other similar bedding material.

Second, the louse lives only by sucking the blood of hogs, and must feed often or will soon become weakened and die from starvation. If newly hatched lice are unable to get food, the majority die within one day after hatching, and the remainder by the end of the second day. The majority of adult lice die within from one to three days, and only a small percentage live as long as five days, after being removed from their host animals. About fifty per cent die by the end of the second day and seventy-five per cent by the end of the third day. It is seldom that a louse lives as long as seven days after being separated from its host.

Third, the female normally does not lay any eggs except on its host. If a female is removed from her host just before she is ready to lay an egg she will usually lay it within twenty-four hours, but as a rule she will not lay when off the host unless compelled by these circumstances to do so, and then she will lay only one egg. A female removed from her host soon after laying an egg will not lay any

more eggs as long as she remains separated from the host. Furthermore, if the female normally laid her eggs anywhere except on the host she would have to get back on an animal very soon after laying and feed again before she could lay another egg, as we have found that egg development and laying cease when the female is removed from her host.

Fourth, as previously stated, the eggs are laid on the base of the hairs and next to the hog's body, which keeps them warm until they hatch. If they were laid in bedding or cracks and crevices about the buildings they would become chilled during the cool nights and days, and eggs which become chilled, especially when first laid, will not hatch.

Fifth, if lice lived anywhere except on the animals they would not multiply as rapidly as we have found them to do under normal conditions.

This conclusion, that the hog louse does not normally infest the animals' quarters, greatly simplifies the question of remedial measures, as only the hogs, and not their quarters, need be treated, thus saving much time, labor, and materials. If any lice should escape treatment by being hidden about the quarters, it would be an easy matter to starve them out merely by removing the hogs to other quarters for five days immediately after the treatment had been applied. But this precaution need be taken only in rare instances, if at all.

TREATMENT

Although it was not the purpose of this investigation to test materials and methods for the treatment of hogs for lice, a few have been used with complete success and some useful recommendations may be made at this time.

There is no doubt that the large amount of blood sucked by the lice is a serious drain on the vitality of the hogs and checks growth and fattening. It has been suggested that lousy hogs may have their vitality lowered to such an extent that they will be more susceptible to cholera and other diseases. Although this may be true, it has not been proved. It would be wise, however, to keep the lice well under control and avoid any risk.

In the treatment of hogs for lice, two questions must be decided; (1) what materials to use, and (2) how they are to be applied. Both will depend to some extent on the number of animals to be treated and the materials and means available.

Many materials and mixtures have been used and recommended to kill hog lice. Some require considerable time for preparation, and hence are not practical for the busy farmer. Fortunately, there are a few comparatively cheap materials which will kill all

the lice and eggs with which they come into contact without injuring the animals.

In general, it may be stated that any oil will kill both lice and eggs. Crude oil, also known as crude petroleum, is one of the best materials, and can be applied as easily as any. Kerosene, or coal oil, mixed with an equal part of cottonseed oil, lard, or other available oil, is equally as good. Axle grease and other heavy greases or pasty materials should not be used, because they are too thick to spread well, and hence are not as effective or economical as thin oils. Proprietary materials, if composed chiefly of oil, are effective, and, if it is known that they do not contain any injurious substances, may be used when they can be obtained and applied more cheaply than other available oils. Medicated oils and disinfectants, however, are no more effective in killing hog lice than the common oils, and should be avoided unless it is known that they do not contain any materials that would injure the animals. Poisonous substances should be avoided because of the danger of poisoning the animals. They have no advantage over the common oils and may not prove as good.

Dust wallows, or dust baths, have been mentioned, but these apparently are of no economic importance and should not be relied upon either to rid the hogs of lice or to keep the lice under control. Mud wallows are of considerable value in helping to keep the lice in check but should not be wholly depended upon.

Whatever method of application of remedies is used, it is necessary to get the liquid on the skin of the animals. This is comparatively easy, since the hairs, or bristles, are coarse and thinly scattered over the body.

When only a few animals are to be treated, and they are easily handled, the liquid may be applied by means of a rag, a sponge, or a brush made of comparatively fine bristles, the liquid being rubbed in so as to wet every part of the animal's skin. Brushes made of stiff, coarse bristles should not be used. If the animals are sufficiently tame to be handled there is no more thorough method of treatment than by hand.

When several animals are to be treated and the hand method is not desirable, a hand sprayer may be used, but it must be of such type that the liquid can be directed against the lower as well as the upper parts of the body. Sufficient pressure must be used to force the liquid through the hair and against the skin. Hogs not accustomed to being handled may be sprayed more thoroughly at feeding time.

When a large number of animals are to be treated the hand method, or possibly the spraying, may not be the most practical. In this case dipping may be resorted to. So many descriptions of dipping vats and their methods of construction and use are published in

agricultural papers, bulletins of experiment stations and the U. S. Department of Agriculture, and other publications that any discussion of them here is not deemed justifiable.

There are many different types of patented hog oilers on the market, and much has been said both for and against their use. While they are effective to some extent, our experiments with them do not show that they are sufficiently effective either to rid the hogs of lice or to keep the lice under control.

How often hogs should be treated depends upon (1) the thoroughness of the application, and (2) the rapidity of increase, from any lice and eggs escaping treatment, as determined from the life-history investigations. If every part of a hog's body is thoroughly wet with oil all lice and eggs will be killed and no further treatment will be necessary unless the animals again become infested. As treatment is generally applied, however, some lice, eggs, or both, will escape. The adult females that escape will continue laying eggs, which will begin hatching approximately two weeks later, and in another two weeks the female lice hatching from these eggs will begin laying. Therefore, if all eggs are killed, but some full-grown lice escape treatment, it will be four weeks before the lice again begin to multiply. If all lice are killed, but some eggs escape treatment, they will hatch in from one to twenty days. Hence, the multiplication of lice will begin within twenty-four hours after treatment. From this it will be seen that it is as important to kill the eggs as the lice, if not more so. The lower half of the body must therefore be thoroughly treated, as most of the eggs are laid there.

If treatment is not thorough some lice and eggs will both escape and multiplication of the pest will continue. Treatment should therefore be repeated every two weeks until the hogs are completely freed of lice. If treatement is repeated only every four weeks the lice can be held in check but not entirely eradicated. It must be borne in mind that lice will never be completely eradicated until one thorough treatment has been given and the treated animals are prevented from coming into contact with other lousy animals; also that lice will crawl from lousy hogs to hogs free from lice if the animals are allowed to come into contact in any way, as, for example, where two herds are separated by a single wire fence, or where they may come into contact by climbing up and standing with their heads and front feet over a low fence.

SUMMARY

1. The eggs, or "nits", of the hog louse are glued to the base of the hairs, chiefly on the lower half of the body. The eggs are laid only on hogs.

2. The louse becomes full-grown and the female begins laying eggs in from eleven to thirteen days after hatching.

3. The female lays from three to four eggs a day. Only one egg is laid at a time.

4. The eggs hatch in from thirteen to twenty days, the majority on the fifteenth, sixteenth, and seventeenth days.

5. The louse normally lives about thirty days, but many lice are injured, killed, and lost from the host before that time. A few have been found to live more than forty days, but this is exceptional.

6. The duration of the life-cycle is normally twenty-nine to forty days, but varies from twenty-four to sixty-three days.

7. The number of generations is usually from nine to twelve per year, but varies from six to fifteen.

8. The best remedy is the application of thin oil. Any oil, or any mixture containing considerable oil, will kill both lice and eggs.

9. Thick, heavy greases or pasty materials should not be used, as they do not spread over the skin well enough to be very effective, and are not economical.

10. Medicated oils, disinfectants, and various proprietary materials are no better than the common oils for killing hog lice, but may be just as good if they contain considerable oil and no substances that are injurious to the animals.

11. Poisonous substances should not be used, as they might poison the animals.

Agricultural Experiment Station

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PRUNING AND SPRAYING THE HOME ORCHARD AND VINEYARD

BY
G. M. BENTLEY

PRUNING A NEGLECTED ORCHARD BEFORE SPRAYING

KNOXVILLE, TENNESSEE

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Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

PRUNING AND SPRAYING THE HOME ORCHARD AND VINEYARD

BY
G. M. BENTLEY

INTRODUCTION

It is the exception today to find a person at all familiar with fruit growing who does not recognize the value of pruning and spraying. Commercial growers for some time have realized that these are paying practices, and have directed their attention to carrying them out. The owner of a small home orchard, although he may appreciate the importance of pruning and spraying, often neglects to give his orchard proper attention. An inquiry directed to many home orchardists as to why they do not prune and spray has brought virtually the same reply from them all; namely, that they do not have a clear understanding of when and how to prune, or the proper spray to use for a given insect or disease, or the correct time for its application. Of the numerous spray solutions and sprayers on the market, they do not know which to select. With these problems confronting him, the home orchardist frequently hesitates to begin the treatment of his trees until they are beyond his control.

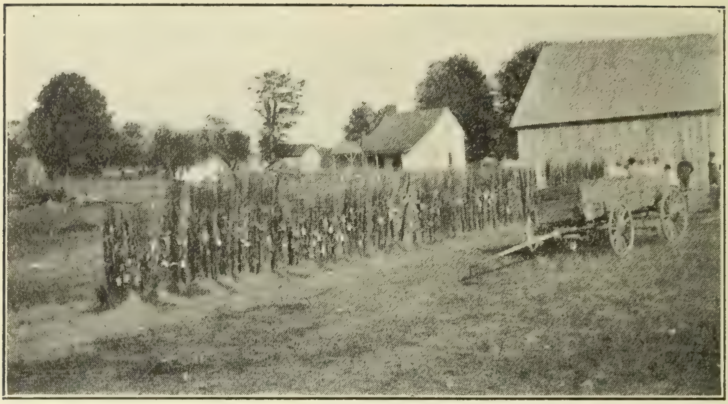
To aid the perplexed grower of the home orchard is the purpose of this bulletin. In order to simplify the proper methods of pruning and spraying, use is made of a number of illustrations, and the reader is advised to study carefully these illustrations and the legends accompanying them. While most of the photographs for the illustrations are original, it is desired here to express appreciation to the U. S. Department of Agriculture, the Deming Company and to the Virginia Experiment Station for the loan of engravings.

GENERAL SUGGESTIONS

A few general suggestions that will apply to most fruit trees should be grasped by prospective orchardists, and those having young orchards.

1. Prepare the ground thoroughly before receiving trees from the nursery, so that they may be set out at once upon arrival.

2. Avoid the common practice of heeling in the trees in a shallow trench to be left throughout the winter months, by which treatment trees may be permanently injured.



Carelessly Heeled-in Trees

Many trees treated this way from late fall until spring become thoroughly dried and in severe weather freeze. It is far better to set the trees soon after they are dug from the nursery. When heeling in for a short time it is necessary to dig a deep trench, not less than 2 feet deep, packing dirt firmly around the roots, giving them a thorough wetting.

3. Plant one- and two-year-old trees rather than three-to-five-year-old; the year-old apple, or one not over two years old, should be used. The June-bud peach (budded in June and sold in October) or the one-year-old tree (from a dormant bud) is the proper selection. Pear, cherry and plum trees may be two or three years old.

Corn Grown in Orchard—Not Advisable

The trees need the plant food and moisture which this crop has taken. Feed the orchard by growing legumes and turning them under, using rye and crimson or red clover as a cover crop during the winter, to be turned under in the spring.

4. Do not plant corn or other grain crops in the orchard; they are too exhausting to the land. Instead grow cowpeas, soy beans or other legumes, turning them under just before the seed has ripened; then in October sow rye and crimson or red clover to give a winter cover crop, which should be turned under in the spring. By this method you supply fertility, which will be needed by your trees.

5. Before selecting trees for your orchard, learn the varieties which do best in your locality. Your State Experiment Station will gladly give you this information.

6. **Do not set an orchard unless you are willing to give it cultivation, pruning and spraying; you will only be throwing money away.**

7. Select the higher ground on your farm for the orchard. This aids the air drainage, and many times prevents injury from frosts.

With the proper attention, trees in Tennessee will yield good crops of perfect fruit, and no farm should be without its home orchard.

TIME TO PRUNE

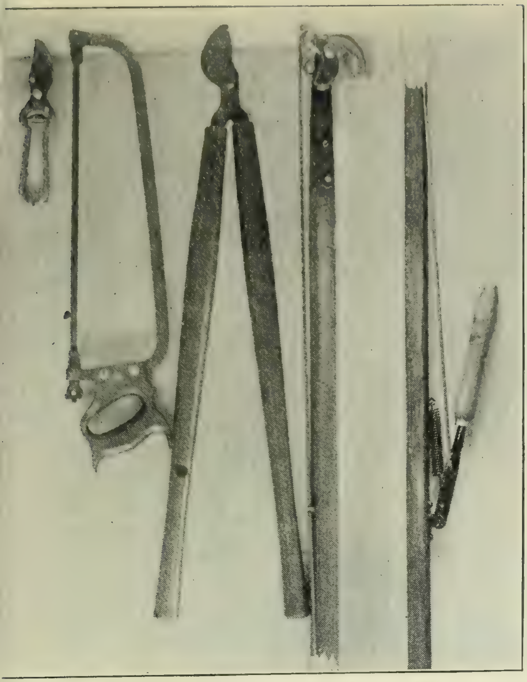
While moderate pruning may be done at any time in the year, excepting for dormant grapes, it is a general practice to prune in February, while the weather is cool, labor is more easily obtained, and there is less rush work. The subject of pruning might well be discussed under the heads of "dormant pruning" and "summer pruning." Heavy pruning of the top in the dormant season tends to increase the amount of wood growth that will be made the following season. In the case of a peach tree filled with old wood, heavy pruning will stimulate the growth of young wood, which is necessary for the production of fruit. When trees are making an excessive amount of wood growth they do not make fruit buds. Checking the growth of the top by pinching it out or by summer pruning will tend to produce fruitfulness. In the case of old trees, typical of the home orchard, which have been neglected, it may take two or three years to transform them into shapely, productive trees. All the pruning should not be done in one year when there are many limbs to be removed. When starting with a young tree it is advisable to do light pruning every year. Dead and diseased branches and those that rub each other should be cut out and burned. Do not leave prunings in or near an orchard to form breeding places for bark beetles, which will later attack the growing trees. Thin out the center of the tree so that the sunlight can get in. It is often advisable to head back the tall branches to induce fruitfulness and to lessen the picking and spraying expense. For a general idea of pruning, study the accompanying illustrations. In the case of orchards that have been growing some years it is desirable to adapt the plan of pruning to the already established form of the tree. If the tree has a well-formed central shaft, prune to this form; if the tree has naturally assumed the vase form, follow that form in pruning.

A Well-Pruned Young Apple Tree

Notice the open center, absence of over-crossing branches, the method of heading in and the number of branches at the fork. This tree has a well-formed central shaft.

Tree Pruned With Open Center

In the previous illustration and this one you see the two recognized types of pruning, viz., the central shaft and the vase form with open center.



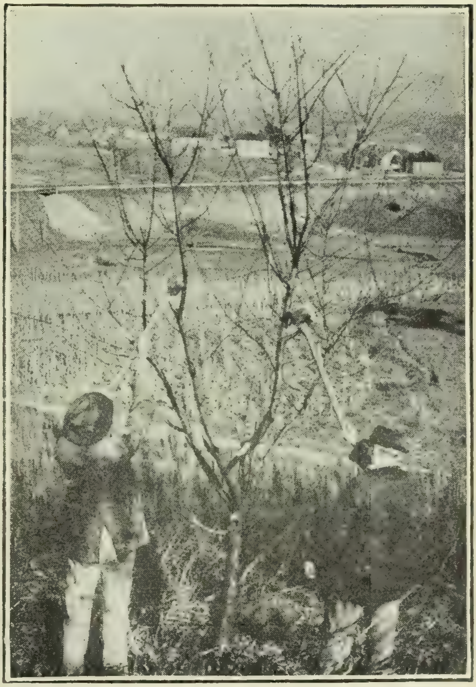
PRUNING EQUIPMENT

The pruning equipment may consist of a pair of hand-pruning shears for the smaller twigs and branches and grapevines; a small saw, with blade that may be set at different angles, which is very desirable for the larger branches; a pair of "dehorning" shears with handles about three feet in length, for heading in; and a pole pruner eight feet in length.

PRUNING TOOLS

Hand-Pruning Shears, Pruning Saw, "Dehorner" and an 8-foot Pole Pruner.

Never use an ax in pruning. It may take years for a tree to outgrow the injury resulting from a few minutes' pruning with an ax. Always avoid leaving stubs or "die back" limbs, as they are sometimes called. Paint all wounds which are an inch or more across with thick paint, not coal tar products.

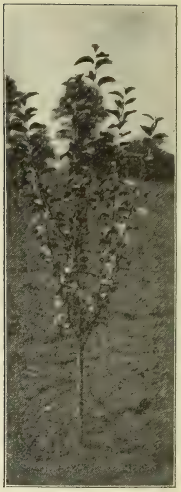


PRUNING WITH THE AX

Avoid this common practice and save your trees serious injury.

ONE-YEAR APPLE TREE CORRECTLY PRUNED

This is a desirable size for setting, and establishes itself quickly.

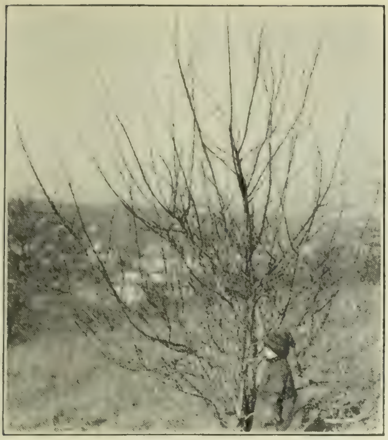


SAME TREE AT END OF SECOND YEAR'S GROWTH

Notice its symmetry and method of branching.

A WELL-CARED-FOR APPLE TREE FIVE YEARS OF AGE

A little pruning each year has kept this tree in good form.



YOUNG APPLE TREE WHICH HAS NOT BEEN PRUNED SINCE IT WAS SET OUT

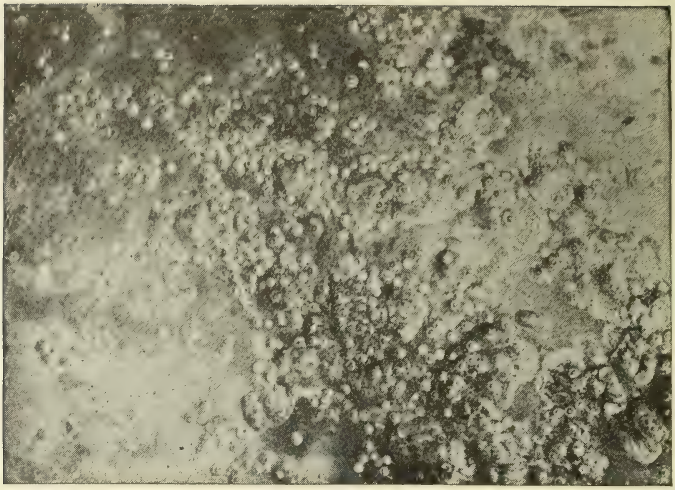
Too many branches, shutting out sunshine and air, will cause inferior fruit, more subject to disease attack.

REJUVENATING AN OLD APPLE TREE

Thinning undesirable water sprouts, cutting out interlocking branches, and heading in the tree as indicated by the white line. Vigor and productiveness would have been conserved had the tree been pruned earlier.

TYPE OF TREE OFTEN FOUND IN THE HOME ORCHARD

Too much wood that is non-productive, tree too high to spray or to pick fruit from economically. Fruitfulness has been retarded by the dense growth.



SAN JOSE SCALE

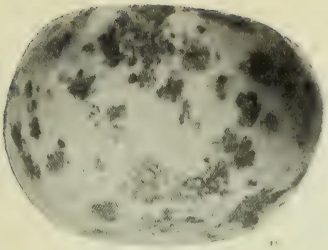
A sucking insect common on the trunks, branches, leaves and fruit when trees are not sprayed. This insect untreated will kill a young peach tree within three years or an apple tree within five years. A satisfactory spray for this insect is the lime-sulphur solution or a miscible oil, applied while the trees are dormant.

FLAT-HEADED APPLE TREE BORER

This common pest is encouraged in an orchard by not pruning, or by not removing dead trees, or by allowing pruned branches or twigs to remain on the ground.

INJURY TO FRUIT BY THE APPLE WORM OR CODLING MOTH

Tennessee produces 2,000,000 barrels of apples per year. Of this amount only 10% is marketable, chiefly due to the attack of the codling moth.

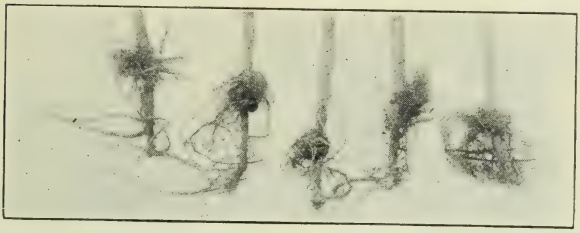


Apple Blotch

This disease attacks the skin of the fruit, often causing it to crack, making the apple unsalable. Apple blotch can be readily controlled by spraying. See spray schedule.

Apple Scab

A very common disease on both fruit and leaves which have not been sprayed. It not only injures the appearance of the fruit but frequently causes early dropping. By spraying according to the schedule given in this bulletin this disease may be prevented on both fruit and leaf.

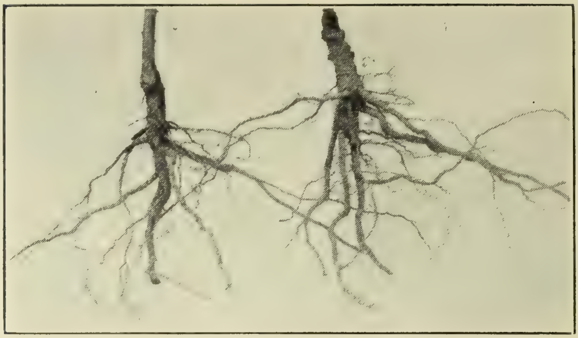


Trees You Should Never Plant

These are young apple trees with roots affected by crown gall and hairy root. Trees thus affected are quarantined in Tennessee. Do not accept them from anyone.

More Trees You Should Never Plant

Roots of young fruit trees affected by the woolly aphis. Notice that the knots are scattered at different places on the roots instead of being in one general position as in trees affected with the crown gall and hairy root.



HEALTHY-ROOTED TREES—THE KIND TO PLANT

These roots are the kind you should have upon your young trees. Notice the well-developed system of taproot and laterals with no knots or enlargements upon them, and no fibrous clusters of small, brittle roots.

YOUNG APPLES, SHOWING THE RIGHT TIME TO APPLY ARSENATE OF LEAD TO CONTROL THE CODLING MOTH

THE BENEFIT OF PRUNING AND SPRAYING

These apples came from a tree which was carefully pruned and given six sprayings to control codling moth and fruit diseases. The apples on the ground are sound; those in the basket are wormy.

RESULT OF FAILURE TO PRUNE AND SPRAY

These apples were gathered in the same orchard as those shown in the preceding illustration. The two trees were of the same variety and age and were standing side by side. The tree that produced these apples was neither pruned nor sprayed, and the full crop is represented by sound fruit in the pile on the right and wormy fruit in the pile on the left.

SPRAY TABLE FOR APPLES

PEST	TIME OF APPLICATION	SPRAY	SUGGESTIONS
San Jose Scale	February or while trees are dormant.	Commercial lime-sulphur solution, 1 to 8, or miscible oil, according to directions.	A dormant spray—3 to 5 lbs. of slaked lime strained and added to the lime-sulphur solution will aid in determining how thoroughly the spraying was done.
Codling Moth, Apple Scab and Black Rot.	When two-thirds of the bloom has fallen.	Lime-sulphur, summer strength, with 1½ lbs. dust, or 3 lbs. paste arsenate of lead to 50 gallons of spray.	First summer spray, time of application most important. The calyx must be open. (See illustration).
Apple Blotch, Bitter Rot, Curculio, Black Rot.	About 3 weeks after the last spray.	Bordeaux mixture (4-4-50) with 1½ lbs. dust or 3 lbs. paste arsenate of lead.	Second summer spray. This will be the last spraying for early apples.
Second Brood of Codling Moth; Apple Blotch, Black Rot and Bitter Rot.	8 to 10 weeks after the bloom has fallen.	Bordeaux mixture (4-4-50) with 1½ lbs. dust or 3 lbs. paste arsenate of lead.	Third summer spray.

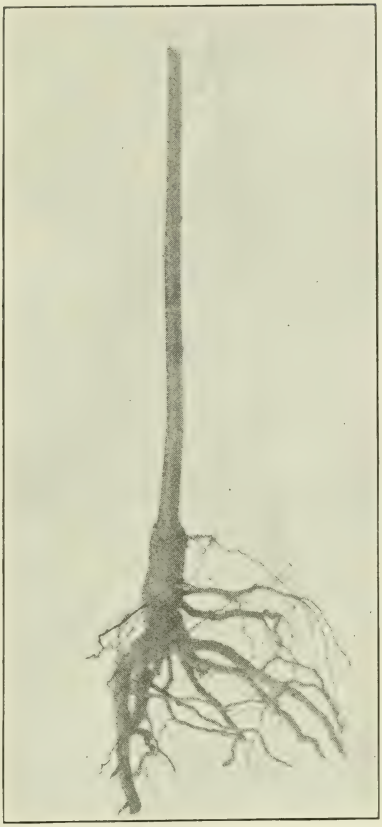
PEACH AND PLUM TREES

The Kind of Peach Tree to Plant

A June-budded or a one-year dormant-budded peach tree is to be selected for planting. Avoid setting the large trees. The medium-sized, young and vigorous tree grows and establishes itself quickly.

Unpruned Peach Tree

This tree is four years old and has never been pruned or sprayed. It has produced no fruit and is infested with San Jose scale.



One-Year-Old Peach Tree, with Roots and Top Pruned Ready for Planting

THREE-YEAR-OLD PEACH TREES

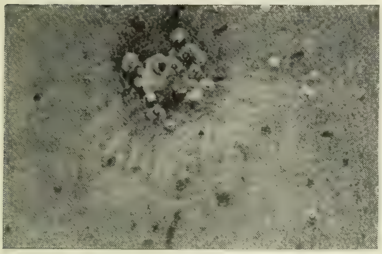
These trees were planted as June-budded trees, have been pruned and sprayed and are heavily set with young fruit.

A "DEHORNED" PEACH TREE

Young, vigorous wood should be kept on the peach tree. Heavy pruning as indicated above often is a direct means of producing fruiting wood and rejuvenating the tree.

Heading In and Thinning out Bearing Peach Trees

The Year-Old Wood Produces the Peaches



San Jose Scale

This is one of the worst peach tree pests, but is easily controlled by a dormant spray of lime-sulphur solution or miscible oil.

Leaf Curl

A disease which is serious some years. It can be very satisfactorily controlled by the use of the lime-sulphur solution as a dormant spray.

The Curculio

a, Full-Grown Larva; *b*, Adult; *c*, Pupa

This insect is commonly known as the peach worm and causes the wormy or waxy peach. To prevent loss from this insect thoroughly spray the peaches about a week or ten days after the petals have fallen, as the shuck is about two-thirds off, with

arsenate of lead, 1½ pounds powdered or 3 pounds paste, to each 50 gallons of water. The arsenate of lead may be used with the self-boiled lime-sulphur solution.

EFFECTS OF THE BROWN ROT

A disease very common on peaches which have not been sprayed. It first appears as a small spot on the fruit just before ripening. It develops very rapidly, and by the time of ripening has spread over most of the fruit. It is the disease that causes peaches to dry and remain on the tree for some time. These are commonly known as "mummied" peaches. Two applications of the self-boiled lime-sulphur solution will prevent injury from brown rot.

DIGGING OUT THE PEACH TREE BORER

This is necessary each spring and fall. By setting the tree deep enough so that the lateral roots are at least six to eight inches

beneath the surface of the soil, much of the injury from this insect can be prevented. Borers can be extracted successfully by a wooden paddle made from a shingle, a stiff whiskbroom, and an awl made by cutting the head off a 12-penny wire nail and inserting the nail in a handle. Pull the soil away from the tree down to the lateral roots, scraping away clinging soil with the paddle. Damp soil may be left until dry, then brushed away with the whiskbroom. In a short time the presence of borers will be indicated by the appearance of red sawdust-like castings. By the use of the awl, the borers can be dug out.

YOUNG PEACHES

Showing correct time to spray for the curculio, or "peach worm." The blooms have fallen; the shucks are two-thirds off.

A COMMON SOURCE OF INFESTATION

Frequently the useless seedling peach tree growing in the fence row is the source from which San Jose scale and brown rot are introduced into the nearby orchard. All such trees should be dug out and burned.

SPRAY TABLE FOR PEACHES AND PLUMS

PEST	TIME OF APPLICATION	SPRAY	SUGGESTIONS
San Jose Scale, Peach Leaf Curl.	February. If highly infested, in late fall after trees are dormant.	Commercial lime-sulphur, 1 to 8, or miscible oil, according to directions.	A dormant spray—select a quiet day, while trees are dry, and spray thoroughly.
Curculio, or the "Peach Worm," Scab.	About one week after bloom has fallen, as the "shuck" is about two-thirds off. (See illustration).	Self-boiled lime-sulphur solution, 8-8-50, to which is added 1½ lbs. powdered or 3 lbs. paste arsenate of lead.	First summer spray. To each 50 gals. of spray add 3 to 5 lbs. of freshly slaked lime. This is to neutralize any free acid in the arsenate of lead.
Curculio, Scab, Brown Rot.	About 3 weeks after the second spraying mentioned above.	Self-boiled lime-sulphur solution, 8-8-50, to which is added 1½ lbs. powdered or 3 lbs. paste arsenate of lead.	Second summer spray. Brown rot appearing at this time, also some curculio.
Brown Rot.	From 3 to 4 weeks before fruit ripens.	Self-boiled lime-sulphur solution, 8-8-50.	Third summer spray. Fine, forcible spray, covering fruit as thoroughly as possible.

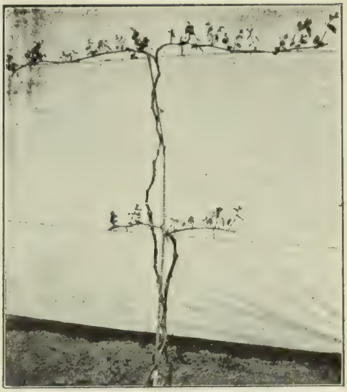
GRAPEVINES

Either one-year or two-year-old vines should be set. The important thing is to set those with well-developed root systems. Before planting, the tops should be cut back, leaving two or three buds on the new growth, and the roots cut back to not more than 10 inches. In Tennessee, fall planting of the grape is prefered. By the third year, at least, some form of permanent support should be provided. This may be a stake or a trellis of some kind.

A two-wire trellis is the most common, the upper wire being about 5 feet from the ground and the lower about 3 feet. For this method of training only two canes are allowed to form, each of which is cut off at a wire and spread out fan-shaped on the wire, as shown in the accompanying illustration.

Another common system of pruning is to use one cane, cutting it off at the top wire and allowing branches to run in each direction on each wire to a distance about half way to the next vine. Another favorite system with the small grower is the method of pruning an old grapevine, as shown in the second illustration. The hand-pruning shears are convenient for grapes, the dormant pruning of which should be done in February. Do not wait until March, when injury would be caused by "bleeding."

All the **summer pruning** necessary is to cut the tips of all advanced shoots with a sharp knife a few days before blooming time, leaving two or three leaves beyond the outer flower cluster. Rub off all buds or shoots on the trunk of the vine below the fork.

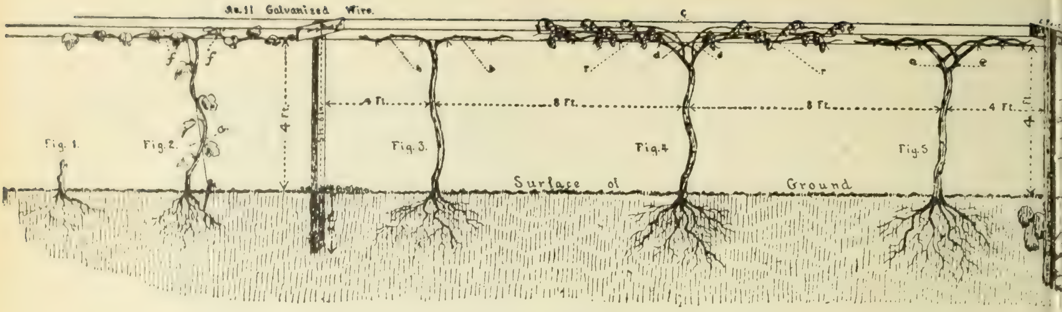


Two-Wire Trellis with Two Canes

The commonest method of training grapevines.

Two-Wire Trellis with One Cane

This illustration also shows the method of pruning an old vine.



THE MUNSON THREE-WIRE CANOPY TRELLIS

Fig. 1 shows vine cut back to two buds.

Fig. 2 shows vine at end of first season's growth trained to lower wire.

Fig. 3 shows vine pruned and tied after first season's growth.

Fig. 4 shows vine bearing the third year.

Fig. 5 shows vine pruned after third season.

EFFECT OF BLACK ROT

A familar sight in vineyards, especially if the weather has been moist and sultry. Practically all of this injury can be avoided by the Bordeaux spray applied as a fog by a strong pressure sprayer.

Dormant Spray—In February, after the grapes are pruned as suggested on pages 36, 37 and 38, they should be thoroughly sprayed with the 5-5-50 Bordeaux solution. Any dry grapes adhering to the vines or scattered upon the ground should be gathered and burned. Spray the vines, trellises and wires, and the ground beneath and around the vines. This dormant spray is to kill the overwintering spores of the black rot.

Growing-Season Sprays—Before the bloom appears, spray with medium-strength Bordeaux solution (3-3-50) to which is added 1½ pounds of powdered or 3 pounds of paste arsenate of lead. After the grapes have grown to about the size of small peas spray thoroughly with the same solution, and about two weeks later spray again, using the same strength Bordeaux solution, to which is added 1½ pounds of

powdered or 3 pounds of paste arsenate of lead. Delicate-skinned varieties, like the Niagara, may now be sacked. A fourth and fifth spraying could profitably be given, using the Bordeaux solution only. By these sprays the black rot, mildew, grape weevil and grapeberry moth will be controlled.

SPRAY TABLE FOR GRAPES

PEST	TIME OF APPLICATION	SPRAY	SUGGESTIONS
Black Rot.	In February after pruning.	Bordeaux solution 5-5-50.	A dormant spray. Thoroughly spray vines and trellises, after "mummied" grapes from vines and ground have been collected and burned.
Black Rot, Downy and Powdery Mildew, Grape Weevil, Grape-Berry Moth.	Before buds open.	Bordeaux solution 3-3-50, plus 1½ lbs. powdered or 3 lbs. paste arsenate of lead.	First and second summer spray. If you have only a few vines and do not care to make the Bordeaux solution, you can buy in varying quantities a ready-made paste of Bordeaux and arsenate of lead, known as Pyrox. If you wish to sack grapes it may be done after this summer spray.
Black Rot, Downy and Powdery Mildew.	After fruit has set.	Bordeaux solution 3-3-50 plus 1½ lbs. powdered or 3 lbs. paste arsenate of lead.	
Black Rot.	Ten days later, or when fruit is about the size of a small pea.	Bordeaux solution 3-3-50.	Third summer spray. All sprays for the grape should be applied with sufficient force to make a fine fog-like mist which will evenly coat foliage and fruit.
Black Rot.	Ten days to two weeks later, grapes two-thirds grown.	Bordeaux solution 3-3-50.	Fourth summer spray. If this and the sprays above have been thoroughly applied, you will be assured of having small loss from black rot, mildew or the grape insects.

SPRAY SOLUTIONS

DORMANT SPRAYS

THE LIME-SULPHUR SOLUTIONS

The sprays made from lime and sulphur may be divided into three classes, viz., the home-boiled, factory-boiled and self-boiled. The first two act both as fungicides and insecticides; the last only as a fungicide. All the lime-sulphur solutions have efficiency and cheapness, which commend them highly.

HOME-BOILED LIME-SULPHUR SOLUTION

Home-boiled lime-sulphur may be made by many different formulas. The one used with best success by the Tennessee Experiment Station is as follows:

Fresh lime (burnt) ....21 pounds
Flour of sulphur ....18 pounds
Water ....50 pounds

Into the boiler, kettle, or tray (a barrel or tank if steam is to be used) place 5 or 6 gallons of water; to this add the sulphur, which has been passed through a flour sieve; then the lime, a small quantity at a time. Fire should now be started under the boiler. After all the lime has been added and the slaking is finished, add water to keep to a good boiling consistency, and boil vigorously from 40 to 60 minutes. The solution is now ready to be thinned. Strain carefully into the spray tank or barrel, adding sufficient water to make 50 gallons of spray.

This spray is for winter, late fall, or early spring use. Never use it while leaves or buds are opening. Never put it into a copper tank or sprayer, for its action upon copper is rapid and will soon ruin a receptacle of this metal.

This spray is for San Jose scale and leaf curl.

FACTORY-BOILED LIME-SULPHUR SOLUTION

A very similar solution can be obtained in concentrated form from factories, known as the factory-boiled lime-sulphur solution. This is usually diluted with from 7 to 8 parts of water to make the winter spray. There are many reliable grades which are as efficient as the home-boiled solution. If good lime cannot be obtained and the proper care given in making the mixture, the factory-boiled solution should be used. The commercial product, at its present price, and of the quality now being furnished, is to be recommended.

MISCIBLE, OR "SOLUBLE," OILS

Instead of the lime-sulphur solutions, miscible, or "soluble," oils may be used according to directions on the containers.

GROWING-SEASON SPRAYS

The weak lime-sulphur solution for summer spray for apples, plums, etc., not including peaches, may be made by reducing the commercial lime-sulphur solution of normal strength at the rate of 1 part to 40 parts of water. For peaches, always use, for the summer spray, the self-boiled lime-sulphur solution, 8-8-50, as described below. To this solution may be added the powdered or paste form of arsenate of lead, in which case from 3 to 5 pounds of freshly slaked lime should be used to each 50 gallons.

SELF-BOILED LIME-SULPHUR SOLUTION

The experiments with the self-boiled lime-sulphur solution for several years have given results which highly commend this spray for the troubles which have heretofore been met with difficulty. Credit is due Mr. W. M. Scott, formerly Pathologist of the Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C., for his preliminary experiments in 1907 and 1908. The following formula, which has given best results, is from Bulletin 174 of that Bureau:

Flour of sulphur.... 8 pounds
Fresh lime (burnt).. 8 pounds
Water ....50 gallons

MAKING THE SELF-BOILED LIME-SULPHUR SOLUTION

Best results can be obtained by making a larger quantity, say four times this amount, as follows: To 8 or 10 gallons of water in a barrel add 32 pounds of fresh stone lime (the quicker-acting the better); when the slaking begins add 32 pounds of fine sulphur which has been run through a sieve to break up all lumps. As the lime continues to slake, water may be added to keep it from drying. The mixture should be constantly stirred until the slaking is over, when

more water is added to stop the cooking. Strain and dilute to make 200 gallons of spray. Only a small amount of soluble sulphur should be present; the desired solution is a mechanical mixture of lime and sulphur. In straining the spray the coarse parts of the lime are to be taken out, but the sulphur worked through the sieve.

HOW AND WHEN TO USE THIS SPRAY

The self-boiled lime-sulphur solution should be applied in the form of a fine spray by a pump equipped with a good agitator. The time for applying will be governed by the disease to be treated. The number of applications may be one, two, three, four or more, according to conditions and the objects sought.

In place of the self-boiled lime-sulphur solution made at home, the commercial concentrated solution may be diluted for summer use. With peach, however, this should be used experimentally. With apple and most other trees except the peach the following reduction gives good results:

Hydrometer reading of the concentrated lime-sulphur solution Degrees Baume	Water to add to one gallon of the commercial concentrated lime-sulphur solution Gallons
35	45
34	43½
33	41¼
32	40
31	37½
30	36¼
29	34¼
28	32¾
27	31
26	29½
25	27¼

The lime-sulphur wash, from the standpoint of cheapness, accessibility, and efficiency, is one of the best sprays known for the San Jose scale.

The time for applying the lime-sulphur wash is while the trees are dormant, as in the late fall, winter, or early spring. Prune the trees before spraying, and spray thoroughly. If all parts of the trees cannot be covered at the first spraying repeat the process soon.

ARSENATE OF LEAD (Liquid)

Powdered arsenate of lead..1 to 3 pounds or 1 tablespoonful
Water ....50 gallons or 1 gallon

or

Paste arsenate of lead....2 to 6 pounds or 2 tablespoonfuls
Water ....50 gallons or 1 gallon

To make a spray, dissolve the dry or paste form of arsenate of lead in a small quantity of water, then dilute to make the desired quantity.

ARSENATE OF LEAD (Dust)

Powdered arsenate of lead	1 pound
Flour, air-slaked lime, road dust or ashes	4 to 10 pounds

TOBACCO SOLUTION

There are today on the market several concentrated tobacco solutions, containing, respectively, 10, 20, 30 and 40 per cent of nicotine sulphate. They are very convenient and may be highly recommended. A desirable formula is:

Nicotine sulphate (40%)	1 ounce
Water	8 gallons
Laundry soap	1 cake

STRONG BORDEAUX MIXTURE

Copper sulphate (bluestone)	5 pounds
Fresh lime (burnt)	5 pounds
Water	50 gallons

MEDIUM BORDEAUX MIXTURE

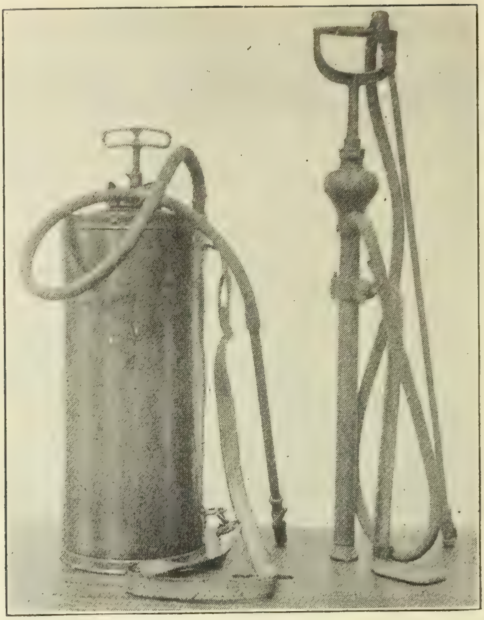
Copper sulphate (bluestone)	3 pounds
Fresh lime (burnt)	3 pounds
Water	50 gallons

Dissolve the copper sulphate by suspending it in a bran bag or gunny sack, in a wooden vessel containing 4 to 5 gallons of water. Slake good burnt lime in another vessel. When ready to use the Bordeaux mixture, pour each of the above-mentioned solutions into a separate barrel, diluting to make 25 gallons. These two solutions may now be mixed by pouring one into the other and thoroughly stirring. The result is 50 gallons of the Bordeaux mixture ready for use. This solution should not be used on peach foliage or fruit.

WEAK BORDEAUX MIXTURE

Copper sulphate (bluestone)	2 pounds
Fresh lime (burnt)	2½ pounds
Water	50 gallons

Separated, the copper sulphate and lime solutions may be kept for some time, but when mixed should be used at once.

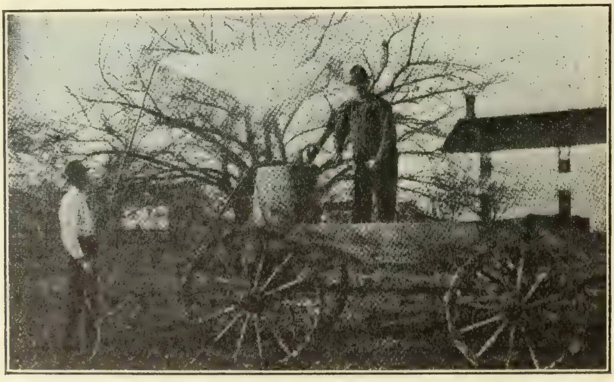


COMPRESSED-AIR CYLINDER SPRAYER—ON LEFT

This type of sprayer, most suitable for spraying grapevines or vegetables, may also be used for a limited number of small trees; also for whitewashing fences and outbuildings and disinfecting chicken houses and stables.

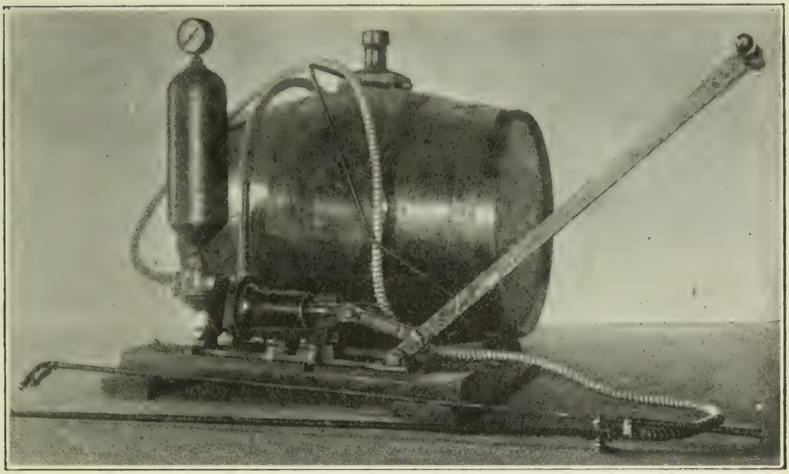
BUCKET SPRAYER—ON RIGHT

An inexpensive, yet efficient type of sprayer, suitable for a small orchard of 10 to 25 young trees. This sprayer becomes a toy in an orchard of several large trees.



A COMMON BARREL SPRAYER IN A FARM WAGON

Equipped with one 20-foot lead of hose and a 6-foot extension rod with a fine angle nozzle.



A Double-Acting Horizontal Cylinder Barrel Pump with Hand Lever

It has a large air chamber with a pressure dial and a mechanical agitator. This pump may be placed in a wagon, or, better, mounted on a sled. It is suitable for an orchard of 50 to 150 trees, and when equipped with a gasoline engine is suitable for a large orchard.

Barrel Sprayer Mounted on Two-Wheeled Cart

Lime-sulphur solution being applied as a dormant spray by mounted barrel sprayer, equipped with two 20-foot leads of hose, and two extension rods with fine nozzles.

Barrel Sprayer Mounted on Two-Wheel Truck

Equipped with 20 feet of hose, a 6-foot extension rod and a fine mist-producing nozzle.

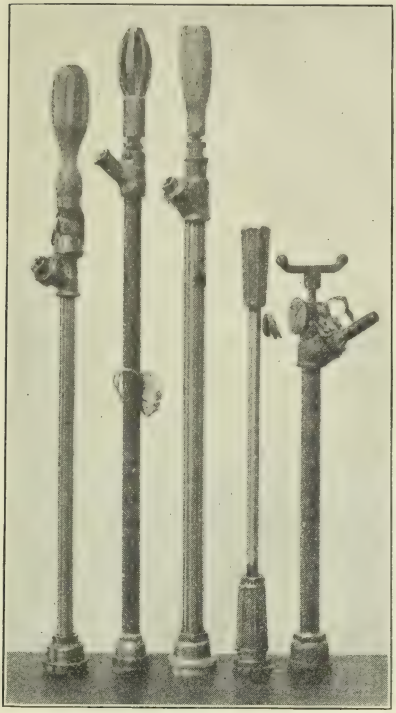
Double-Acting Sprayer Mounted on Sled

This method of mounting a sprayer is to be recommended, since many of the Tennessee orchards are located on high, sloping land.

NOZZLES OR "SPRAY GUNS"

The forms of spray nozzles have changed greatly within the last few years, as spraying has developed and become more practical and efficient. The nozzle today should be simple, without projecting plunger screws or cleaners to catch and hang upon the twigs and branches, as the nozzle mounted upon an extension rod is hurriedly thrust up into the tree and withdrawn as the spray is being applied. The nozzle should produce a fine, forcible cone-shaped spray, or mist, similar to a fog. When an extension rod is used it is of great advantage to have the nozzle mounted at an angle or quarter turn. The latest type of nozzle is known as a "spray gun," or "orchard gun," consisting of a metal cylinder from 15 to 30 inches in length, equipped with a steel disc nozzle at one end and a round handle or grip at the other, connecting the nozzle with a plunger rod, either inside or outside the cylinder. A slight grip or turn of the handle completely cuts off the spray or changes the amount of liquid leaving the nozzle. With this type of nozzle no extension rod is needed, nor spray tower to elevate the operator. Actual orchard experience has proven the "spray gun" a great saver of time and spray material, provided the operator is alert in his movements and cuts off when making shifts. A pressure of at least 175 pounds is needed for the "gun" to do its best. For the commercial orchardist its use is advised as the best type of nozzle now known. The size of the home orchard or vineyard and the use of the power sprayer will determine the practicability of the "gun" for the small grower.

To Spray or Not To Spray Is No Longer The Question.
Spraying Is Insurance And Is Essential.



Different Types of "Spray Guns," Handles at Top, Nozzles at Bottom

YIELD FROM SEVEN WIDELY SEPARATED, SPRAYED ORCHARDS COMPARED WITH SAME NUMBER UNSPRAYED

37 per cent more Fruit.

15 per cent more Perfect Fruit.

7 per cent more Second Grade Fruit.

$1.62 per Tree, net profit.

$97.20 per Acre, net profit.

Agricultural Experiment Station

OF THE

University of Tennessee

BULLETIN NO. 122 | APRIL, 1919

A COMPARISON OF AZOTOBACTER WITH YEASTS

BY

MAURICE MULVANIA

KNOXVILLE, TENNESSEE

The Agricultural Experiment Station

OF THE UNIVERSITY OF TENNESSEE

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*Deceased Jan. 28, 1919.

The Experiment Station building, containing the offices and laboratories, and the plant house, are located on the University campus, 15 minutes walk from the Custom House in Knoxville. The experiment farms, the barns, stables, dairy building, etc., are located about one mile west of the University, on the Kingston Pike. The fruit farm is adjacent to the Industrial School, and is easily reached by the Lonsdale car line. Farmers are cordially invited to visit the buildings and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

A COMPARISON OF AZOTOBACTER WITH YEASTS

BY

MAURICE MULVANIA

The morphological resemblance of *Azotobacter*, in many of its cytological forms, to yeast cells is apparent when attention is centered on this particular characteristic. The large spherical and oval forms, with their bud formation, suggest at once close likeness to the normal reproductive budding of yeasts. This resemblance has been pointed out by some authors and must have been observed by many others.

From time to time the writer has observed a number of striking similarities between *Azotobacter* and certain yeasts, and during the past few months has had opportunity to make a direct and somewhat detailed comparison of these organisms, both morphologically and physiologically.

The accompanying tables seem to cover the more essential characteristics—those which are thought to differentiate yeasts from bacteria—although they do not, of course, exhaust the subject.

TABLE I—*Morphological comparison*

ORGANISM	SHAPE					Spores	Vacuoles	Buds	Nucleus	Flagella
	Coccus	Oval	Rods		Polygons					
			Small	Large						
Pink yeast	—	x	x	x	x	—	x	x	—	—
White yeast	x	x	—	x	x	x	x	x	x	—
Azotobacter	x	x	x	x	x	x	x	x	x	x

TABLE II—*Physiological comparison*

ORGANISM	Alcoholic fermentation Bouillon		Acid from sugar Bouillon		Assimilation of N.	Growth in ether
	Glucose	Mannite	Glucose	Mannite		
Pink yeast	x	x	—	—	x	—
White yeast	x	x	—	—	x	x
Azotobacter	x	x	—	—	x	x

TABLE III—*Sugar fermentation by yeast and Azotobacter*

ORGANISM	Solution	Incubation period					
		6 days		20 days		40 days	
		Growth	Gas	Growth	Gas	Growth	Gas
Yeast	Sucrose M*	x	—	x	—	x	—
	Sucrose P	x	—	x	—	x	—
	Dextrose M	x	—	x	—	x	—
	Dextrose P	x	—	x	—	x	—
	Glucose M	x	—	x	—	x	—
	Glucose P	x	—	x	—	x	—
	Maltose M	—	—	—	—	—	—
	Maltose P	—	—	—	—	x	—
	Mannite M	x	—	x	—	x	—
	Mannite P	—	—	x	—	x	—
Azotobacter	Sucrose M	x	x	x	3%	x	3%
	Sucrose P	x	—	x	—	x	—
	Dextrose M	x	—	x	8%	x	8%
	Dextrose P	x	—	x	6%	x	6%
	Glucose M	x	—	x	8%	x	8%
	Glucose P	x	—	x	9%	x	9%
	Maltose M	x	—	x	1%	x	1%
	Maltose P	x	—	x	1%	x	1%
	Mannite M	x	—	x	—	x	—
	Mannite P	—	—	—	—	—	—

M = Mineralized solution = $K_2HPO_4 + MgSO_4 + CaCl_2 + Fe_2Cl_6 + 1\frac{1}{2}\%$ sugar in distilled water.

P = Plain solution = $1\frac{1}{2}\%$ sugar in distilled water.

The tabulations for *Azotobacter* consist of facts gathered from observations of some twenty cultures, isolated from as many different places on the Tennessee Experiment Station Farm. No one of these cultures showed all the qualities here presented. All, however, were undoubted representatives of this group of organisms. Two cultures of yeast were used. One was secured from a commercial yeast cake known as Fleischmann's compressed yeast; the other was a wild pink yeast from the air of the laboratory. It was not thought necessary to include more cultures of yeast, as the writer was more interested in determining the yeast-like characters of *Azotobacter* than the bacteria-like characters of yeast.

The concordance shown in Tables I and II is so nearly complete that choice of conclusions is hardly possible. On the basis of this evidence alone we are virtually compelled to believe that we are concerned with three members of a single narrowly restricted group of organisms.

In Table III is shown a rather uniform set of results as concerns the ability of these organisms to grow in sugar solutions. The gas-

producing quality is confined to *Azotobacter*, never having been observed in either yeast. These results were secured as an average condition of eight cultures for each solution. With some sugars, however, *Azotobacter* has no gas-producing quality.

The predominant shape is not the same for any two of the organisms studied. Thus, *Azotobacter* appeared oftenest as a distinct rod of medium size, while the white yeast was usually a large oval body. The variations, however, from the typical of any one were sufficient to coincide with almost all the variants of each of the other species. As shown in the table, these variations range from medium rods, through many gradations, to large spheres.

Large oval and round cells of *Azotobacter* are frequently observed to break up into a number of refractive bodies, which give a granular appearance to the entire cell. These have been looked upon as dying or disintegrating cells, but the writer's observation of these granules has convinced him that they are reproductive bodies capable of immediately developing into new vegetative individuals. This is strikingly like the spore formation of yeasts, in which a single cell becomes a sporangium, whose contents break up into a number of spores, variable with the species. Cauda[1] refers to this breaking up of the cytoplasm of *Azotobacter* as a process of spore formation, and concludes from this and other considerations that this organism should be classed with the *Schizophyceae* instead of the *Schizomycetes*. *Azotobacter*, in fact, has never been satisfactorily included in any of the well-established groups of *Eubacteria*, and it could certainly never be regarded as a typical bacterium.

Reproduction of *Azotobacter* by means of buds has been observed by many investigators, but this is not nearly so common as it is in the vegetative stage of ordinary commercial yeasts. There appears to be no authentic record of budding among bacteria; hence, this property has considerable significance in this connection. Whether or not the nucleus takes the same part in the budding of *Azotobacter* as is assigned to it in typical yeast budding, the writer has been unable to determine. The nucleus was observed only when the organism was seen as an oval or rod, whereas budding is seen mostly in the large coccus-like forms. The nucleus could not be distinguished in any of the budding forms.

The nucleus was stained usually by the method suggested by Wager, and quoted by Chamberlain[2], for staining the nucleus of *Saccharomycetes*. It can be seen, however, in stains made with methylene blue on the usual cover-slip preparation. It is always centrally located, is round, and has a diameter of from .1 to .2 micromillimeter, while the cell is from 1 to 2 micromillimeters long by 1 to 1.5 broad. No details could be made out concerning the structure of the nucleus, the stain being taken uniformly by the entire body.

1—Le Stazioni Sperimentali Agrorie Italiane, Vol. 49, Facs. 2.

2—Methods in Plant Histology.

Paravincini[1] has observed the nuclei of several bacteria, and was able to trace nuclear divisions previous to each division of the cell. If these results are accepted the nucleus as a distinguishing characteristic between bacteria and yeasts is eliminated.

The spores formed by *Azotobacter* do not possess the resistance to heat usually observed in the endospores of bacteria in general. A temperature of 90° C. for five or six minutes is sufficient to kill them completely. Likewise yeast spores do not withstand the extreme heat which the spores of bacteria do. This fact may or may not have taxonomic value, as there is, of course, considerable variation in this regard among well-recognized bacteria.

Different authors have expressed opposite views concerning the ability of yeasts to use free atmospheric nitrogen in their metabolic processes. Zikes[2] observed a *Torula* which assimilated free nitrogen. Hinze[3], working with various lower organisms, came to a similar conclusion. DeKruijff[4] described a nitrogen-fixing *Torula*. Kossowicz[5] held that certain yeasts could assimilate free nitrogen, but later[6] he reversed this opinion, maintaining that the combined nitrogen of the air was used by these organisms. Linder and Newman[7] could detect no accumulation of nitrogen by the yeasts which they studied.

The question of nitrogen assimilation by yeasts is therefore still in doubt, and the writer can only add one more to the list of those who have been convinced by experiments that certain forms of yeast can use free nitrogen as a supply of this element. His experiments seem to eliminate the latter contentions of Kossowicz, as the combined nitrogen of the air was washed out before the air was introduced into the culture flasks.

Every bacteriologist who has considered the recent conclusions of Lohnis and Smith[8] on the life cycle of bacteria must have felt the necessity for extreme modification of our accepted views to bring them into harmony with the contentions of these authors. Much more revolutionary will it seem if we are compelled to align yeasts and bacteria in the same category as concerns their life-history.

Azotobacter, having supplied the basic material for the initial studies of the authors named above, must have furnished the original idea of a complex life cycle. The subsequent inclusion of other organisms proved to them that the processes of *Azotobacter* are typical of all bacteria. Now, if *Azotobacter* is in reality a yeast we are compelled to believe that yeasts and bacteria pass through the same cycle. This conclusion can hardly be accepted by microbiologists without much additional evidence.

1—Centb. f. Bact. and Inf. Abt. 2, Bd. 48, No. 16-19 (1918), pp. 332-340.

2—Ztizber. K. Akad. Wiss. [Vienna] Math. Naturw. Kl. 118 (1909), pp. 1091-1133.

3—Landw. Jahrb., 35, No. 6, pp. 889-910.

4—Ann. Jard., Bot. Butten. Zorg. (1910), Sup. 3, Pt. 1, pp. 93-96.

5—Ztchr. Garungsphysiol., 1 (1912), No. 3, pp. 253-255.

6—Biochem. Ztschr., 64 (1914), No. 1-3, pp- 82-85.

7—Wehnschr. Proc., 30 (1913), No. 47, pp. 589-592.

8—Jour. Agr. Research, VI, 18, pp. 675-702.

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University of Tennessee
Agricultural Experiment Station
Knoxville

BULLETIN NO. 123 APRIL, 1921

LESPEDEZA
(Japan Clover)

BY

S. H. ESSARY

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University of Tennessee
Agricultural Experiment Station

H. A. Morgan, President

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The Agricultural Building, containing the offices and laboratories of the Experiment Station, the College class rooms, and the headquarters of the Division of Extension, is located at the University farm, on Kingston Pike, about one mile west of the University. Farmers are cordially invited to visit the building and experimental grounds.

Bulletins of this Station will be sent, upon application, free of charge, to any farmer in the State.

LESPEDEZA
(Japan Clover)

By

S. H. Essary

SUMMARY

1. Lespedeza (*Lespedeza striata*), or Japan clover, was introduced into the Southern States from eastern Asia some time before the Civil War. Its present range is from New Jersey west to Kansas and south to the Gulf. It reaches its greatest importance in the southern part of the Mississippi Valley. Over the rest of its range it is valuable chiefly for pasture and soil improvement. It grows in all parts of Tennessee, but ranks in importance with other legumes only in the western part of the State.

2. Lespedeza ranks well with alfalfa and the clovers as a valuable forage plant, and is superior to them in many situations, especially as a renovator of worn lands.

3. Lespedeza is an annual, coming from seed each year, but under practically all conditions where it grows it reseeds itself. Common varieties have a spreading habit when the plants are scattered, but in thick stands grow erect. Flowers are produced from the middle of summer till frost, and ripen an abundance of seed.

4. Lespedeza is often confused with hop clover, but is readily distinguished from hop clover by the time of development, color and form of flowers, and shape and arrangement of leaves.

5. Many native species of *Lespedeza* are found in Tennessee. They are all perennial, and none of them resemble Japan clover enough to be mistaken for it. They are of little agricultural value.

6. Lespedeza should be seeded early in the spring, on a well-prepared seed-bed, and covered lightly. It may be seeded in grain or grass crops, but should be sown in the spring following the seeding of the other crops. A bushel of seed to the acre should be sown when lespedeza alone is grown, but with other crops a smaller quantity is required.

7. When harvested for hay, lespedeza should be cut before the leaves drop or the stems become hard. When harvested for seed, the cutting should be deferred till the end of the growing season, usually about the time of frost. The hay in either case should be

handled carefully, as the leaves and seed shatter off easily. Curing is commonly done in shocks, and it is a good practice to cover the shocks with hay caps made of cotton sheeting.

8. Lespedeza seed may be threshed from the hay with a grain thresher or collected in a seed pan attached to the cutter bar of the mowing machine.

9. The seed of lespedeza germinate well when fresh. About 50 per cent of two-year-old seed germinate. Seed three years old or more should not be planted.

10. Lespedeza is inoculated wherever found growing in Tennessee, and no artificial inoculation is required. It gathers a considerable amount of nitrogen from the air.

11. The addition of lime to the soil has a beneficial effect upon the yield of lespedeza hay. This effect was found to last at least three years.

12. Lespedeza is a good pasture plant, whether grown alone or in combination with grasses. The best results are obtained when it is in combination with crops that make a good early spring growth.

13. Lespedeza compares very favorably with other legumes in yield of hay. The yield depends upon the season, the stand, and the fertility of the soil. Two tons to the acre is about an average yield on good soil, but four tons is not an unusual yield. The seed yields vary as much as the hay yields, and run from four or five to twenty bushels per acre.

14. Crabgrass is the most common weed in lespedeza fields, but other weeds are often present. It is necessary to mow the fields once or twice during the summer to remove the weeds, after which the lespedeza will control them. Dodder is frequently a source of serious trouble. There are few insect or parasitic enemies of lespedeza.

15. Common lespedeza is not a single variety, but a mixture of slightly differing varieties, which can be separated into early or late, small or large varieties.

16. The Tennessee Station has selected and propagated three new varieties, which seem to be superior to the mixture usually grown. One of these is well adapted for hay, one for pasture, and one for growing in sections of the State where the season is short. These varieties are described in this bulletin.

17. Lespedeza will not take the place of alfalfa and the clovers, but will supplement them, in that it will grow on any kind of soil and is easily and cheaply grown and handled. It also comes into a field naturally, which the others do not, and makes good pasture and hay, about equal in value to those of the other legumes mentioned.

INTRODUCTION

Lespedeza (*Lespedeza striata*), or Japan clover, is a native of eastern Asia. It is found growing wild in China, Manchuria, Mongolia, Korea, and Japan, but is not widely cultivated, if at all, in those countries. Just when or how it was introduced into America is a debated question. It was found and described in Georgia in 1846. The first specimen described is still preserved in the Gray Herbarium. Seed is supposed to have been brought to this country accidentally in packing material with shipments of goods from Japan. The popular belief is that it was introduced during the Civil War and widely scattered by the movement of armies over the South. The plant was common throughout the Southern States soon afterward, but for some years was not regarded as having any value. It was known as wild clover and was considered as an undesirable weed, for the reason that it was supposed to cause injurious slobbering in horses.

RANGE

It is found growing at present from New Jersey westward to Kansas, and southward, through Texas, to the Gulf. Over most of this area it grows only as a wild plant in pastures and waste places. From Tennessee and North Carolina southward it is sown for pasture and hay, but only in the alluvial valleys has it reached its greatest value.

IN TENNESSEE

As far as known, it began to be noticed in Tennessee about forty years ago, growing along roadsides, in meadows and waste places, over the western part of the State. Its value in grass pastures was soon recognized, and after a few years it was cut for hay, along with native grasses. It was not commonly sown for hay and pasture until within the last fifteen or twenty years. Its recognized value as a soil improver is of recent date.

COMMERCIAL IMPORTANCE

As a hay crop, it was first grown on an extensive scale by Col. J. B. McGhee, in Louisiana, in 1880. At present it is considered as one of the most important forage crops over a large part of its range, thriving better than any other legume on all types of soil. In Mississippi, Louisiana, Alabama, and eastern Texas it reaches its maximum usefulness. The larger part of the seed found on the market is from Louisiana and Mississippi. The general belief of most growers is that seed from the far south produces more vigorous crops than that grown farther north, but there is no conclusive proof to bear out this opinion.

HABITS

Lespedeza is an annual. The young plants come up early in the spring, make slow growth till midsummer, then develop rapidly, ripen seed, and die down after the first killing frosts. Some early varieties grown at the West Tennessee Station mature and die before the first frosts, thus showing that frost is not the limiting factor in the growth of this plant. No plants have been found which live over winter. The whole plant, including the roots, dies late in the fall. One variety grown at the Station seems to be somewhat frost-resistant, and remains green until the ground freezes. This is probably due more to the late-maturing habits of the plant than to a tendency to become a perennial. The young plants seldom appear early enough in Tennessee to be killed by late spring frosts. In West Tennessee young plants frequently appear in February, but in no case has it been observed that they are killed by frost, to which they seem to be more resistant than old plants. Where the young plants are protected by stubble of the previous year's crop, they make considerable growth before warm weather, and even where seed is sown on freshly prepared land without any protection the young plants survive late frosts.

GROWTH

The plants are upright in growth when young, but later the side branches take the lead, and they tend to become spreading, if not too closely crowded. Where the plants are very thick on the ground the side branches do not develop, the main stem taking the lead and growing to a height, varying with soil and moisture, up to 30 inches under the most favorable conditions. Where plants are alone, or the stand is thin, they spread out a foot or more in width. They rarely grow over six inches tall. In our experiments, where the plants are allowed to stand 36 inches apart, they often reach a width of three feet, and in a few cases plants have been found 42 inches across, and weighing, when dry, with all the branches and roots attached, about half a pound. The branches spreading on the ground take root at the nodes. The roots of very large plants have been found penetrating the hard clay soil to a depth of 24 inches.

FLOWERING AND SEEDING

Lespedeza begins flowering in Tennessee about the middle of July in an average season. The flowers bloom one at a time in clusters in the axils of the leaves, and may be overlooked. The number of flowers to the cluster varies from one to a dozen, and there may be flowers and ripe seed in the cluster at the same time. The flowers are about a sixteenth of an inch across, blue or purple in

color, and remain open only a short time, usually withering up the same day they bloom out. There is only one seed in a short pod to each flower. The ripe seed with its seed pod, called the husk, sheds off readily. As the husk is not easily removed, the seed are usually found on the market unhulled.

Most species of *Lespedeza* have two kinds of flowers; one kind blooms out, and the other does not. Both kinds, however, make good seed. Japan clover seems to have this habit. Mature seed are always found on the branches under the plants, near or on the ground, where apparently they have not bloomed out. In two Chinese species grown in our experiments a large part of the seed is matured from the flowers that do not open, and it is possible to distinguish the two kinds of flowers in the bud stage. As no insects have been seen visiting the flowers of lespedeza, it is evident that the flower is self-fertilizing.

There has been no evidence to show that there is any mixing of varieties. Several strains or varieties have been grown side by side in rows for a number of years, yet they have apparently not crossed. Attempts at artificial crossing have not succeeded. The flowers are small and delicate, and nearly always drop off when crosses are attempted. Trials at crossing lespedeza with other species have all failed. The two Chinese species mentioned may have been crossed naturally, as some of the plants looked like crosses of the two. They were not studied further, however, as they appeared to be of no commercial importance.

LESPEDEZA AND HOP CLOVER

Lespedeza is often confused by the farmer with hop clover. The two can be readily distinguished by the flowers and leaves and the time at which the plants develop. Lespedeza seed germinate in the spring and make slow growth till June, whereas hop clover seed germinate in the fall, and the young plants remain green throughout the winter. Hop clover starts growth early in the spring, the plants ripening seed and dying down before lespedeza makes much growth. This alone would distinguish the two plants. The leaves are about the same size, and look much alike, each consisting of three leaflets at the end of a short stalk. In lespedeza they stand at the same level, but in hop clover the middle leaflet is raised slightly above the two lateral leaflets. The lespedeza leaflet is smooth on the margins, without a notch at the end. The midrib extends slightly beyond the end of the leaflet. Hop clover leaflets are slightly broader toward the end, wedge-shaped below, and slightly toothed, and have a decided notch at the end. The flowers are very different. Those of lespedeza are blue or purple, and those of hop clover are yellow. Lespedeza flowers are on very short stalks, in clusters, while hop

clover flowers are on long flower stalks, in heads, and the flowers all bloom about the same time. The heads turn brownish without shriveling up, and remain on the plant. The dried heads resemble hops; whence the name "hop clover". The seed of lespedeza are about two-thirds the size of red clover seed, but flatter and dark in color, and remain in the seed pod, while those of hop clover are about the color and size of white clover seed, and shell out very easily. There are two common varieties of hop clover in Tennessee, and often they are found growing side by side. One is larger and somewhat later than the other. The larger is the more common. The smaller has fewer flowers, arranged in looser but smaller heads.

NATIVE SPECIES

There are a number of native species of *Lespedeza* in Tennessee, but none that resemble Japan clover sufficiently to be mistaken for it. They are all perennials. The tops die down in the fall, but the roots live over winter. They are found growing in woods and waste places; none are cultivated, as they are of no agricultural value. A few other foreign species have been imported, but none of them have proved of much value.

PLANTING

The most favorable time to plant lespedeza in Tennessee is early spring. The seed germinate rather slowly, and if sown in February will generally germinate some time in March, too late for frosts severe enough to kill the young plants. In self-seeded fields the young plants may appear in late February. Fall seeding has not been tried experimentally, but it is reasonable to believe that seeding done too late in the fall for the seed to germinate before spring might prove satisfactory. An early stand is desirable since lespedeza requires a long growing season for best results. Seedings made in this State as late as June 15 have ripened some seed, but made very poor yields of forage. It is hardly worth while to sow later than the middle of April with the expectation of getting a profitable crop the first year. One bushel (25 pounds) to the acre of good seed in the husk is usually sufficient to insure a good crop for hay or pasture the first year. If it is desired to get only enough plants to reseed the ground, a smaller amount may be used. Even one peck to the acre will produce enough to reseed the ground completely. Trials at the West Tennessee Station have shown that one bushel to the acre gives better results than either more or less than this amount.

The seed are sown broadcast, either by hand or with a clover seeder. A clover seed drill opened wide has been found very good for planting lespedeza. The covering of the seed should be very light. If covered more than one-fourth inch they may not come up to a

stand. A good rain following broadcasting of the seed will generally effect all the covering that is desirable. If a drill is used it should be set very shallow. Running over the ground with a roller of the cultipacker type after sowing the seed has been found at the Station to cover the seed sufficiently, and at the same time pack the land into a good, firm seed-bed, which is very desirable.

PREPARATION OF THE LAND

The land should be well prepared before planting. It should be broken if hard, disked and harrowed, and brought to a fine seed-bed. At least as good preparation should be given as for either red clover or alfalfa. When lespedeza is to be sown on other crops, oats or redtop, for example, the land should be gone over lightly with a harrow before seeding, and possibly harrowed again after seeding. This will not injure the oats or grass seriously, and will insure a good stand of lespedeza.

HARVESTING

The best time for harvesting lespedeza depends upon the purpose for which it is harvested.

If cut for hay, the best time is when the plants are full-grown, but before the leaves begin to shed. This will depend upon the season, but will usually be in September or early October. A part of the seeds will be ripe at this time, but there will still be flowers at the tops of the plants. It has been found best to cut the hay in the morning after the dew is off and rake it into windrows in the afternoon of the same day. It may be left to finish curing in the windrows or put up in shocks the following day and left there to finish curing. The per cent of moisture in lespedeza is low, and curing takes place very quickly in the shock. If the weather is damp the rack used in curing alfalfa hay can be used to advantage. Some of the most careful lespedeza growers use hay caps to protect the hay against rain, and also to preserve the green color, as sunburned, or brown, hay is less desirable and brings a lower price on the market. The hay is of better quality if allowed to cure in bulk rather than in the swath after the mower. It not only is brighter and greener, but is said to be more palatable to stock on account of the aroma imparted to it by curing in bulk. The leaves are also preserved on the stalk. Hay which consists mostly of stems has a very poor sale on the market. Lespedeza should be handled as little as possible because of the tendency of the leaves to shatter off.

If the crop is to be cut for seed it should be left till most of the seed are ripe, generally, in Tennessee, about the time of the first killing frosts, or the middle of October. Some of the leaves will have dropped off at this time and the stems will be more woody. The

cutting should be done with a good mower, having a very sharp blade, and before the dew is off in the morning. The hay is raked into windrows in the afternoon and shocked the same day if possible. The shocks should be capped and allowed to stand till dry. The smallest possible amount of handling is best, since lespedeza seed shatter more readily than those of any other legume.

COLLECTING SEED

In the far south, where much of the commercial seed is grown, the hay is threshed on a grain thresher with special lespedeza attachments, or with the concaves removed. The farmer can get all the seed needed for his own use by beating the hay on a tight floor or a sheet, and fanning the leaves and dirt out with a good fanning mill. The hay may be hauled on a frame with a tight bottom, and a considerable amount of seed collected in this way. Some farmers get enough seed on the floor of the barn loft after the hay is removed to supply their needs.

Another method of collecting the seed is known as the seed-pan method. A specially constructed pan of galvanized iron is bolted on the cutter bar, and drags behind the blade. The pan is as long as the blade and about 30 inches wide. It has a lid of corrugated metal hinged at the front so that it may be opened to remove the seed. The lid is perforated with half-inch holes at the bottom of the corrugations for the seed and leaves to fall through into the pan. These are taken out at intervals and sacked and allowed to dry, or spread out to dry, then cleaned by fanning once or twice. Seed collected in this way are of better quality than threshed seed, because only mature seed are obtained in cutting the hay. The seed pan may be used to advantage when cutting lespedeza for hay, as a good portion of the seed will be ripe at this time. One can judge of the amount of ripe seed by the amount collecting on the cutter bar of the mower. Enough seed will be shattered off to reseed the ground even when the seed pan is used, if there is enough ripe seed to justify the use of the pan. At present very little, if any, lespedeza is threshed in Tennessee, but there is no reason why it could not be threshed. Many farmers are gathering enough seed for their own use, and some for their neighbors, by the pan method.

The weight of a bushel of well-cleaned lespedeza seed in the husk is 25 pounds. No one has used a huller to clean the seed. A clover seed huller probably could be used, but it is a question whether this would pay, as the seed is easily handled in the husk.

In Louisiana an attachment is used for bunching the hay as it is cut. This is on the order of the old-fashioned grain reaper. The farmers of Middle Tennessee use a machine constructed on this plan for harvesting ripe crimson clover. This might prove to be a good

machine with which to harvest lespedeza. If a combination of the seed-pan and bunching machine were on the market, it might be of great value in harvesting lespedeza seed, but so far no such machine is known. The main difficulty in using such a machine would be in removing the seed from the pan, which has to be done at frequent intervals. When the seed pan is used an extra man is required to keep the hay raked off the pan, and this at best is no easy matter. If the lespedeza is mixed with crabgrass, as is often the case, cutting is very difficult at the time of harvesting for seed. The construction of the seed pan used at the Station is shown in the accompanying picture (page 27). This pan is manufactured by a firm in Baton Rouge. Some makes have a number of iron rods across the pan instead of the lid shown in the illustration.

HAY CAPS

Hay caps are usually made of cotton sheeting about three or four feet square. Sheeting is better than canvas because it gives all the protection necessary against rain, and allows the moisture from the hay to escape. It is not necessary to cover more than the top of the shock. The caps must be fastened to prevent their being blown off. Various means are used for this purpose. Sticks may be tied to the corners, and thrust into the shocks, or weights may be tied in the corners. Considerable care has to be taken in fastening the caps.

GERMINATION

Well-matured seed give a high per cent of germination when fresh, but the germination decreases rapidly when the seed are kept over. An experiment made at the Station with seed one and two years old showed that one-year-old seed, out of ten samples taken, gave germinations of from 32 to 80 per cent, while two-year-old seed gave only from 12 to 64 per cent. Seed three years old gave much lower results, but a few seed will remain germinable longer than three years. In 1920, seed from the 1915 crop were sown thick in rows. A few plants came up late. It is not safe to sow seed more than two years old, and if two-year-old seed have to be used the amount should be doubled. In all samples tested there were a few hard seed left on the germinator at the end of the experiment.

Experiments carried on at the Louisiana Station[1] showed that three-year-old seed failed to germinate, and two-year-old seed gave a low germination. In each case the hard seed left over germinated when tested later. It was also found that seed treated with sulphuric acid germinated very rapidly, within three or four days. At the Tennessee Station seed have never been found coming up the second year after planting. Tests were made by placing seed in the

ground at different depths. They were dug up at intervals and examined. After one year, all the seed placed deeper than one inch below the surface were decayed, with the exception of a few hard seed, which failed to germinate when tested in the laboratory. The trial was continued for three years, and a few hard seed were found at the end of that time.

INOCULATION

Lespedeza, like other legumes, has nodules produced by certain soil bacteria, which gather nitrogen from the air and store it in these nodules in the form of nitrogenous compounds. The bacteria penetrate the roots, increase rapidly in number, and, at the points where they are located, stimulate the growth of the roots, thus forming the nodules. These nodules, which are small knotlike growths, or tubercles, of varying sizes, the largest being about the size of a small pea, can be observed on the roots of the plants wherever the latter are found. The nodules decay, and the nitrogen is either taken up by the plant for its own growth or left in the soil to be used by future crops. Since lespedeza is inoculated wherever found, these bacteria would seem to be very common in our soils.

Burrill and Hansen[2] divide the nodule bacteria into nine groups according to the legumes upon which they grow. They found, for example, that the bacteria in lespedeza nodules attack the native species of *Lespedeza*, cowpeas, peanuts, velvet beans, beggarweed, and a number of other wild legumes; that is, bacteria from any one of these plants will produce nodules on any other. They found that the several varieties of red clover, alsike, crimson, and white clover constitute another group; the common garden peas, field peas, vetches, and sweet peas, another; and garden and scarlet runner beans still another. They found that soybeans stand alone, being inoculated by bacteria which do not attack any other legume. These experiments did not include all the common legumes, wild and cultivated, but the authors explain why some soils are inoculated for some legumes and not for others. They also explain why a plant like lespedeza is so commonly inoculated, there being few soils in which some of the plants of its group have not been growing recently.

Garman and Didlake[3] make the assertion that cowpeas are not inoculated by the bacteria found on any other plants. Lespedeza, however, was not included in their trials.

AMOUNT OF NITROGEN GATHERED

The amount of nitrogen assimilated by lespedeza is considerable. Dodson[4] found that 76 per cent of the dry weight of the whole plant

is usually cut for hay, leaving 24 per cent of stubble, roots and leaves on the ground. Chemical analysis showed that 1.65 per cent of the roots and stubble and 2.28 per cent of the stems and leaves were nitrogen. Some of the nitrogen left in the soil is lost by leaching, and perhaps otherwise. As some nitrogen is taken by the plant from the soil itself, it is doubtful if more would be added than is taken from the soil when the hay is removed; but when the whole crop is turned under the increase in fertility is shown by the increased yields in crops following it. According to Dodson's calculations, when an acre of ground yields three tons of hay there will be one ton of stubble and leaves left on the ground. Counting 1.65 per cent of this as nitrogen gives a total of 33 pounds of nitrogen to the acre, nearly as much as is furnished by 500 pounds of high-grade cottonseed meal. If the whole crop were turned under it would be equivalent to about 2500 pounds of cottonseed meal. In addition to this, the physical condition of the soil is much improved by the lespedeza.

YIELDS OF HAY AND SEED

The amount of hay harvested from a lespedeza field will depend upon the soil, the season, the time of sowing, and the stand. It is commonly said among farmers that each four inches in height of a good stand will make a ton of hay to the acre. The fact is that lespedeza makes a surprisingly large yield, considering the appearance of the field. This is accounted for by the very thick stand, together with the small amount of water in the plants. Unless the stand is at least six inches tall, mowing is hardly advisable, as the blade will run over much of a short stand. One or two tons of dry hay is common, while three or four tons to the acre is not unusual on good land. In a few instances, on certain fertile bottom lands in West Tennessee, as much as five tons is said to have been obtained. In such cases the stand is pure lespedeza and very tall, 24 inches or more.

The yields of seed vary considerably. Frequently where the hay yield is very large the amount of seed obtained is small. The most seed is made by a fair stand on moderately good soil. Half a bushel of seed sown on an acre will produce more seed than a very heavy seeding. The Station plots were found to yield from four or five bushels up to twenty bushels in exceptional cases. Our No. 76 has yielded an average of about six bushels to the acre, collected with the seed pan, and not threshed, and enough was left on the ground for reseeding.

INFLUENCE OF LIME AND FERTILIZERS

In the spring of 1914, a range of ten one-fortieth-acre plots was laid off on thin gray land of the West Tennessee Station. One-half of each plot was limed with ground limestone at the rate of two tons per acre. The plots were fertilized according to the plan given in Table 1. The hay was mowed about the middle of October and weighed green each year for three years. A computation of the hay yield was made from a five-pound sample taken from each half plot, and thoroughly dried and weighed again. No other lime or fertilizer was added after the first application. The stand of lespedeza was better the last two years than the first. The hay yields of each half plot estimated in pounds per acre are given in Table 1.

TABLE 1—FERTILIZER AND LIME EXPERIMENTS WITH LESPEDEZA

Plot	Fertilizer per acre in pounds	Yields of hay per acre in pounds					
		1914		1915		1916	
		Limed	Unlimed	Limed	Unlimed	Limed	Unlimed
1	None	1728	512	3808	2272	3072	2688
2	1000 lbs. acid phosphate	1504	608	3840	3968	4288	3840
3	500 lbs. muriate potash	1344	832	3968	2368	3456	2688
4	100 lbs. nitrate soda	1312	416	2976	2272	3616	2496
5	None	2016	1248	3520	2400	3904	3040
6	1000 lbs. acid phosphate 500 lbs. muriate potash	1152	960	3840	3488	5440	4032
7	1000 lbs. acid phosphate 100 lbs. nitrate soda	2560	1440	4960	3200	5536	4544
8	500 lbs. muriate potash 100 lbs. nitrate soda	1024	928	3488	2752	5568	4864
9	None	2508	2016	4320	2976	5760	4832
10	1000 lbs. acid phosphate 500 lbs. muriate potash 100 lbs. nitrate soda	1536	1248	4320	4320	5568	5440
	Average gain per plot of limed over unlimed	647		902		794	
	Per cent of gain	63		30		20	

It will be observed that on this soil commercial fertilizers did not influence the yields to an appreciable extent, but that the increase from lime is marked, although it drops off from year to year. Similar results were obtained in other trials on this farm. At other stations it has been found that acid phosphate did increase the yields.

For example, at the Water Valley branch station of Mississippi it was found that the addition of 400 pounds of acid phosphate nearly doubled the yield of hay.[5]

SOIL RENOVATION

There is no doubt that lespedeza greatly improves old and worn soils. Many old, abandoned fields in the western part of the State have been brought back to a state of cultivation by the growth of lespedeza which came in naturally. One of the chief values of lespedeza is in the fact that no soils are too poor to make some growth, not even the clay of gully banks where little else will grow. With its nitrogen-gathering powers, it gradually builds up the land, and at the same time checks erosion until other crops can thrive. Old lespedeza fields are found very desirable for cotton and corn, not only on account of the fertility, but of the improved mechanical condition of the soil. It is a well-known fact among farmers that lespedeza lands bring a relatively high rental. The claim is made that they produce a higher grade of cotton than other lands. The same is true with regard to tobacco. Why the quality of the crops following lespedeza is improved is not clearly understood, but there is a general belief that such is the case.

PASTURES AND LESPEDEZA MIXTURES

There is no doubt in the minds of farmers that lespedeza makes a good pasture, whether grown alone or in a mixture with grass. The carrying power of many pastures may be increased 25 per cent or more by the addition of lespedeza. The main objection to a pure lespedeza pasture is that it comes on very late in the spring. This disadvantage is removed when it is sown in a mixture with grasses that make an early pasture, especially as lespedeza stays green late in the fall after the grasses are exhausted. In combination with bermuda, bluegrass, or redtop it makes an ideal pasture for horses, cattle, and sheep; but it is objected to somewhat as a hog pasture on the ground that it becomes too tough in the fall. There are very few pastures which do not contain lespedeza as a constituent.

The objection previously mentioned that it causes slobbering is not serious, since slobbering ceases after a few days, when the animals have become accustomed to this kind of feed. It is thought by some observers that slobbering is not caused by lespedeza, but by hop clover. There seems, however, to be little doubt that lespedeza will cause slobbering in some cases. This is true of other closely related plants as well, especially white clover and alsike.

Lespedeza and redtop sown together will not only make a good all-season pasture, but will make two good hay crops in a season, the redtop being cut in June, and the lespedeza in October. Bermuda

and lespedeza also make an excellent permanent pasture. In some parts of the South carpet grass is used instead of bermuda. It has about the same habits as bermuda, but is not grown in Tennessee. Crabgrass appears in most lespedeza pastures. This mixture makes a good pasture, and the crabgrass adds materially to the yield of hay. Redtop and lespedeza are both sown in the spring in Tennessee, and both crops will continue until broomsedge comes in and spoils the pasture.

IN ROTATION

Many combinations of lespedeza with other crops may be made for the purpose of rotation. One favorite rotation with farmers in the far South is oats and lespedeza. The oats may be sown in the fall and lespedeza the following spring. After that, lespedeza will perpetuate itself. It is necessary only to disk the lespedeza stubble as a preparation for sowing oats in the fall. A three-year rotation of corn, oats, and lespedeza is also a favorite one. The first year corn is harvested; the second year oats and lespedeza are harvested; the third year lespedeza alone is harvested or turned under for corn the fourth year.

Cotton may be substituted for corn the fourth year, thus making a corn, oats, lespedeza, and cotton rotation. The advantage of oats and lespedeza in these rotations is that they are both quickly harvested, at a time when other farm work is slack, the oats in May or June and the lespedeza in October. These rotations provide for money crops, such as are grown in the South, and a legume to plow under for improvement of the soil. Lespedeza may be allowed to stand more than two years, thus extending the rotation to any length. Mr. A. D. McNair[6] outlines two systems of rotation suited to the South. These are given in Tables 2 and 3.

TABLE 2—A FOUR-YEAR ROTATION OF COTTON, CORN, OATS AND LESPEDEZA

Year	First field	Second field	Third field	Fourth field
First	Cotton	Corn with cowpeas	Oats followed by lespedeza	Lespedeza
Second	Corn with cowpeas	Oats followed by lespedeza	Lespedeza	Cotton
Third	Oats followed by lespedeza	Lespedeza	Cotton	Corn with cowpeas
Fourth	Lespedeza	Cotton	Corn with cowpeas	Oats followed by lespedeza

In the rotation given in Table 2 cowpeas are to be planted between the corn rows. Here we have six crops, counting cowpeas, in four years: one money crop—cotton; two cereals for money or feed—corn and oats; two hay crops for money or feed—lespedeza; and a pasture or fertilizer crop—cowpeas. Lespedeza is also a fertilizer crop. By dividing the farm into four fields it is possible to obtain all six crops each year.

TABLE 3—A FOUR-YEAR ROTATION FOR A DAIRY FARM, WITH LESPEDEZA FOR HAY AND PASTURE

Year	First field	Second field	Third field	Fourth field
First	Corn with cowpeas	Soybeans or peanuts	Oats and lespedeza	Lespedeza
Second	Soybeans or peanuts	Oats and lespedeza	Lespedeza	Corn and cowpeas
Third	Oats and lespedeza	Lespedeza	Corn and cowpeas	Soybeans or peanuts
Fourth	Lespedeza	Corn and cowpeas	Soybeans or peanuts	Oats and lespedeza

A four-year rotation of corn, oats and lespedeza, has been maintained at the West Tennessee Experiment Station for a number of years, as follows: First year, corn; second year, oats and lespedeza; third and fourth years, lespedeza. The land had been in lespedeza three years before the first crop of corn. On another range, corn has been grown continuously. The yields of corn from representative plots of both ranges are given in Table 4. The plots were fertilized as indicated each year for the whole period.

The following four-year rotation used by Mr. W. N. McFadden, Warren, Tennessee, has been found very satisfactory:

1st year—Corn or cotton.

2d year—Oats, seeded to redtop and lespedeza.

3d year—Hay (redtop and lespedeza).

4th year—Pasture.

WEEDS

In newly sown lespedeza, weeds are likely to grow rank and overtop the lespedeza, especially on fertile lands, or, when the stand is thin, on any kind of soil. To overcome this trouble the weeds should be mowed once or twice before the middle of summer. After

TABLE 4—COMPARISON OF CONTINUOUS CORN WITH ROTATIONS OF CORN, OATS, AND LESPEDEZA

Range	Plot	Rotation	Fertilizer	Yields of corn in bushels per acre		
				1912	1916	1920
1			5 tons manure			
	13		200 lbs. acid phosphate			
			50 lbs. muriate potash	55.35	48.50	63.57
		Corn	67 lbs. nitrate soda			
	14		5 tons manure	54.28	45.00	48.92
	15		None	40.71	33.50	26.42
	17		None	47.14	28.50	27.85
2	23	1st year Corn	None	54.18	55.70	70.35
	26	2d year Oats and lespedeza	None	57.20	56.75	80.56
	27	3d year Lespedeza	200 lbs. acid phosphate 50 lbs. muriate potash	56.40	53.90	94.62
	28	4th year Lespedeza	None	54.80	49.25	79.64

that the lespedeza will make such rapid growth that the weeds will be held in check. The most common weed in this section is crabgrass; but in wet lands smartweed gives much trouble. The second year the stand of lespedeza is usually thick enough to take care of the weed situation. In very thin soils, the so-called "poor John" is a very common weed, its habit of growth being somewhat similar to that of lespedeza. Crabgrass, unless too abundant, does not damage the quality of the hay seriously. In old pasture mixtures, the grass commonly called broomsedge will become so plentiful as to necessitate the plowing up of the pasture.

The well-known clover dodder may be very troublesome in lespedeza in some seasons. Unless taken in hand early in the season, when it first makes its appearance, it is very difficult to eradicate. Hand-picking will destroy it if done early and thoroughly, and as often as the dodder becomes noticeable. It is readily identified by the bright yellow thread-like vines running over the plants. As the dodder is attached to the plant, the part bearing it, or better, the whole plant, should be removed from the field. Where dodder is in large patches in the field all the plants within these spots should be hoed up and piled into heaps, with the dirt dug up, in the middle

of the spots, in order to kill the dodder. Dodder seed are not very common in lespedeza seed, especially if the seed are collected by the pan method, as they do not shatter off when the hay is cut. Lespedeza or clover containing dodder should not be harvested for seed.

ENEMIES

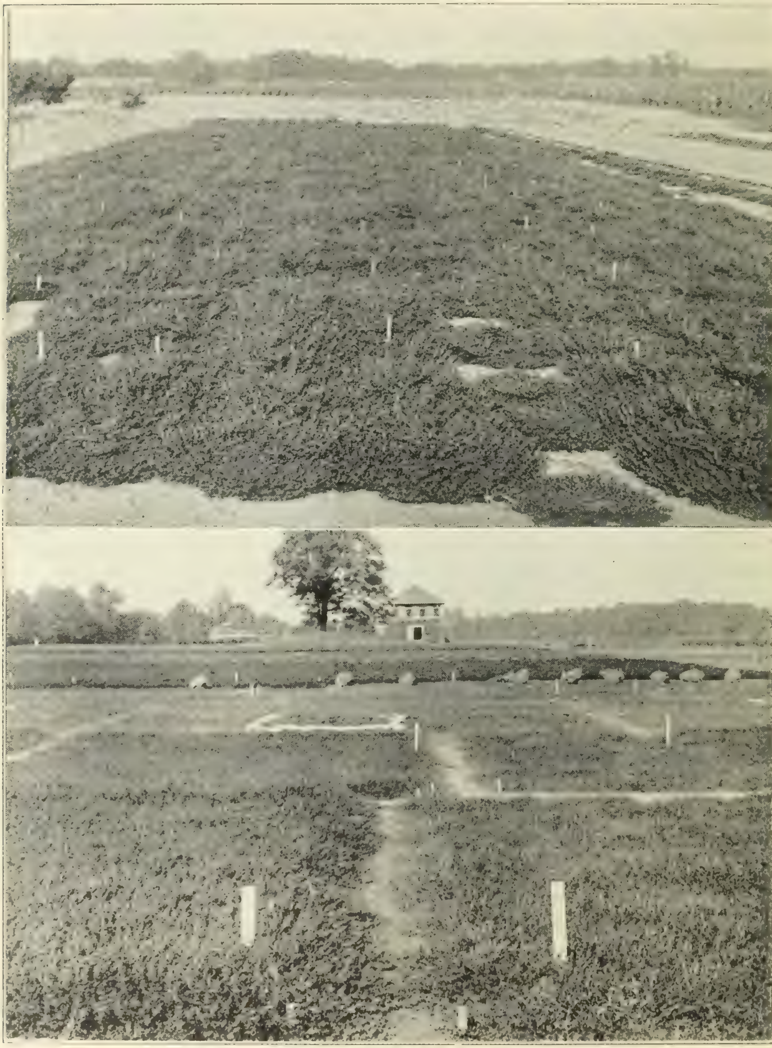
Lespedeza is practically free from fungous or bacterial diseases, such as attack other legumes. Occasionally, a small patch of a peculiar bluish moldy appearance is found, caused by a slime mold that is frequently found on lawns. This does very little damage to the crop. A common mildew is often found growing on the leaves, but this disease is unimportant in Tennessee. Insect attacks are also rare. Grasshoppers cause some damage, but this is slight. The larva of the smoky crane fly (*Tipula infuscata*) is reported to have completely destroyed a stand in a field in Madison County in 1908.[7] This insect is common in that section, but it has not been observed causing trouble since the date mentioned. It is well known in the adult stage as a large, long-legged, mosquito-like insect, swarming around grass and clover fields in the fall. The larva, called a grub or maggot, lives in the soil and subsists on the roots of legumes and other plants. The damage reported occurred in the month of March, when lespedeza plants are very small.

IMPROVED VARIETIES

In the fall of 1912, work was begun at the Tennessee Agricultural Experiment Station on the life-history, habits, and improvement of lespedeza. The project was later extended to include a study of its adaptation to uses as a hay and pasture plant, and as a soil improver, on the various types of soil of the State.

Two hundred and fifty-eight selections of seed were made, some from single plants, some from groups of plants growing wild, and some from the fields of lespedeza grown from market seed. These seed selections were sown in rows 24 inches apart, on the West Tennessee Station farm, in the spring of 1913 (page 20). The rows were cultivated to keep the weeds out, and close observations were made throughout the season. Differences between the selections were soon apparent. The seed of some selections germinated much earlier than those of other selections; the plants of some were larger; of others earlier; and there were variations in color. All had the spreading habit of the commonly grown variety.

Seed were selected again from all these rows, and sown in rows and plots the following spring. The rows were placed 36 inches apart, and the plants the same distance apart in the row, thus giv-



Lespedeza Selections in Rows.

Lespedeza Selections in Plots. Stakes are Same Height.

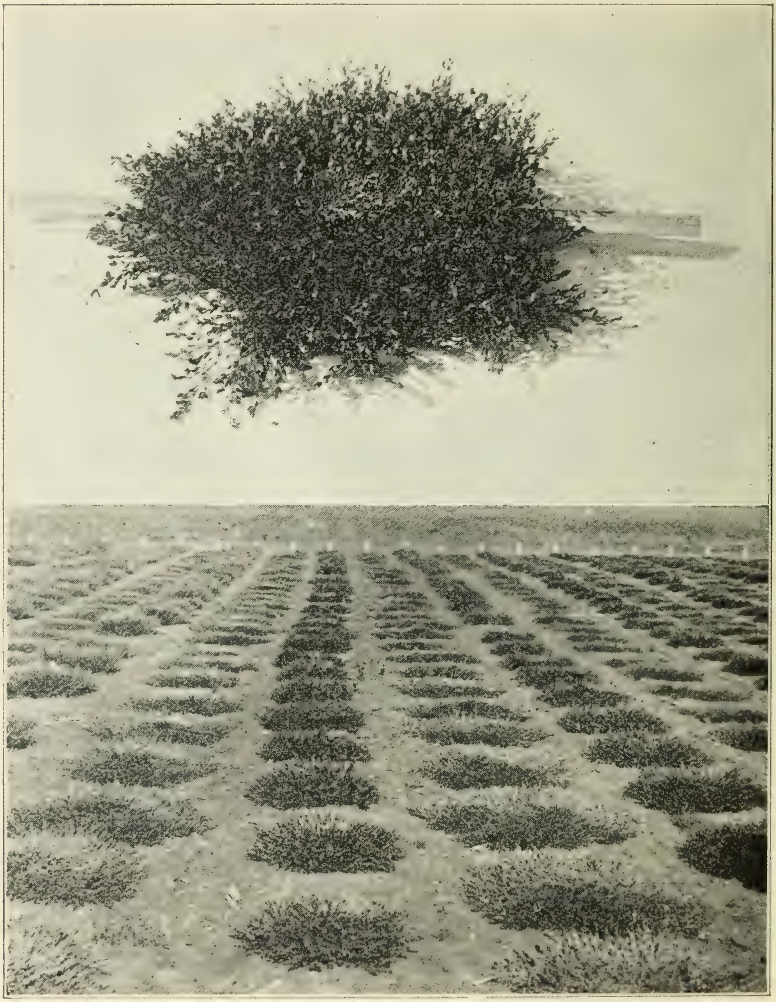
ing each plant opportunity to grow without interference. This was done in order that the individual differences of single plants might be studied. The plots were treated about the same as ordinary fields of lespedeza, except that the weeds were kept out.

Differences between the selections as to size and earliness were again very marked. The plants in rows grew to a very large size, a few of them being 42 inches across. With one exception they were of the usual spreading type. In No. 89 there was one plant rather bunchy instead of spreading, and with many fine branches and many leaves. This plant was so different from any other in the plot that it was selected for further study. Another selection, No. 46, was much larger than any other, and it was selected as a good type of the spreading plant. No other rows showed any remarkable characteristics. A large number of selections were discarded that year because they were much alike, or else too small to be of any value. The plots showed the same differences as to size, earliness, and color that the rows showed the previous year. Some of the selections made large yields of hay compared with others. Some were so short that they were not thought to be worth harvesting. The seed yields varied as widely as the hay yields.

The following year all the remainder of the selections were planted in rows both at Knoxville and at Jackson. From this time on, with a few exceptions, rows represented single plants of the previous year. The plants in the row from the bunchy plant, No. 89, were all like the mother plant. A new variation appeared in No. 76. Five plants at Knoxville, in one row, and two plants at Jackson, in a plot, were different from any others. They were taller, nearly upright in growth, and held all the branches up off the ground.

Seed were gathered from each of these seven plants for progeny rows the following year. The bunchy plants from No. 89 and the upright plants from No. 76 were given these numbers, respectively, and have been carried on as new varieties since that time under these numbers. They have remained true to type in a remarkable degree, and are easily distinguished from all other selections either in rows or in plots. Many other slight variations have appeared in other selections, but they have been so nearly like the common variety that they have been discarded. Only the best one of the common spreading types has been kept in the experiment. This is No. 46, previously mentioned.

In the fall of 1915, a search was made in the Smoky Mountains of Sevier and Blount Counties for stray plants of lespedeza. The plant grows abundantly in the valleys of those counties, but as the elevation increases it gradually disappears. A few plants with ripe seed were found at Indian Gap, just over the state line, in North Carolina, at an elevation of about 4500 feet.



Original Plant of the New Variety No. 89.

No. 89 in Center and Second Row to Right. Dark Color Indicates Frost-Resistance.

The seed were planted in rows at Jackson the following year. The progeny of only one plant differed enough from the ordinary kind to be thought worth keeping. They were of the usual spreading type, but developed very early in the spring, flowering, ripening seed, and dying some weeks ahead of the other selections. While the plants are rather small, and of no importance in most sections of the State, this variety was kept and propagated as possibly being suited for sections north of the present range of lespedeza, and in high and cool parts of the State. It will not be valuable except in pasture mixtures and for soil improvement where other legumes are not suited for those purposes. This variety has been designated as "M".

The three varieties, No. 89, No. 76, and M, have been kept and propagated for comparison with No. 46, a good type of the large, spreading kind. They have been sown in ranges large enough for comparison as to their value for hay and for pasture. No. 76 makes from one-third to one-half more hay than either of the others. No. 46 ranks second. No. 89, while third, makes an abundance of fine pasture, and remains green till killing frost. Nos. 76 and 46 make large yields of seed, while No. 89 makes only enough to reseed the land well, about a bushel to the acre, collected with the seed pan. M makes a good crop of seed, but is too short to cut with profit.

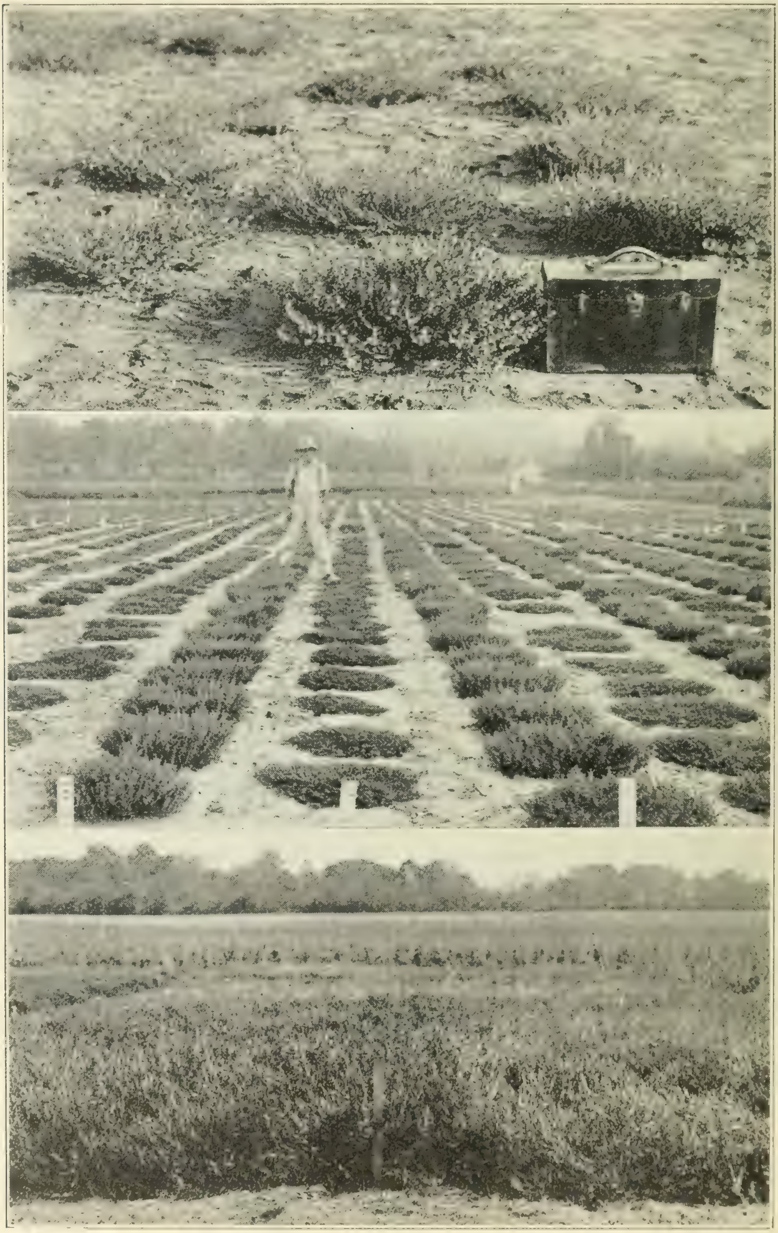
DESCRIPTION OF FOUR VARIETIES*

No. 46. Plants spreading when growing alone, central stem short, branches long, lying on the ground, and taking root at the nodes, many small branches forming a mat on the ground. Branches turn upward at the ends. Plants upright when grown close together, the central stem taking the lead in growth. Begins flowering about the middle of July, and ripens an abundance of seed by frost. Useful as a hay and pasture plant.

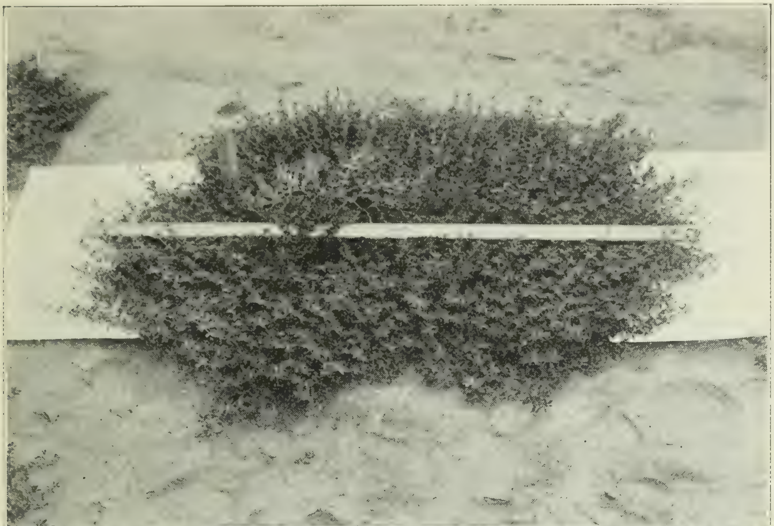
No. 89. Plants bunchy when grown alone, branches numerous and short, very leafy. Central stem very short. Flowers late, and makes few seed. Somewhat frost-resistant. The original selection was made in a hay field in Gibson County, grown from commercial seed; origin not known. Plants upright when grown thick. Makes only a fair yield of hay. This is considered a good pasture variety because of its lateness and leafy habit.

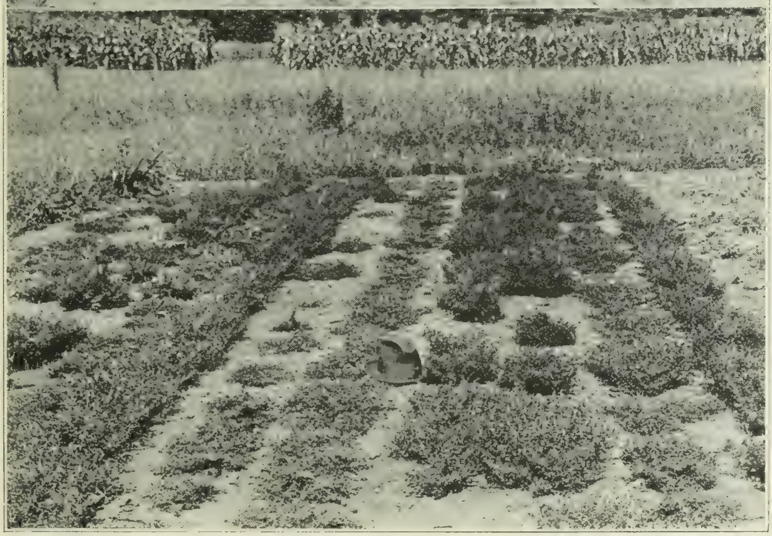
No. 76. Plants tall when grown alone; branches numerous, ascending, held up off the ground, and shorter than branches of No. 46. Flowers from the middle of July till frost, and ripens an abundance of seed. In thick seedings it grows much taller than any other variety, and makes, on the average, a third more hay. Well adapted for hay and pasture. The original selection was made in a

*These are considered as varieties only in an agricultural, not a botanical sense.



Plants of No. 76, a New Upright Variety. Height 14 Inches.
Rows of No. 76 Contrasted with Rows of Spreading Plants.
Thickly Sown Plot of No. 76. Stake in Center 18 Inches High.





A Single Plant of the Spreading Type, 42 Inches Wide, as Shown by Yardstick.

Varieties of Lespedeza in Rows. Left to Right, Beginning at Corner: 76, 46 (4-Year-Old Seed), M, 76, 76, 89, 76.

field in Henderson County, mixed with native grasses. Lespedeza had never been sown in that neighborhood; hence the origin of this selection is not known.

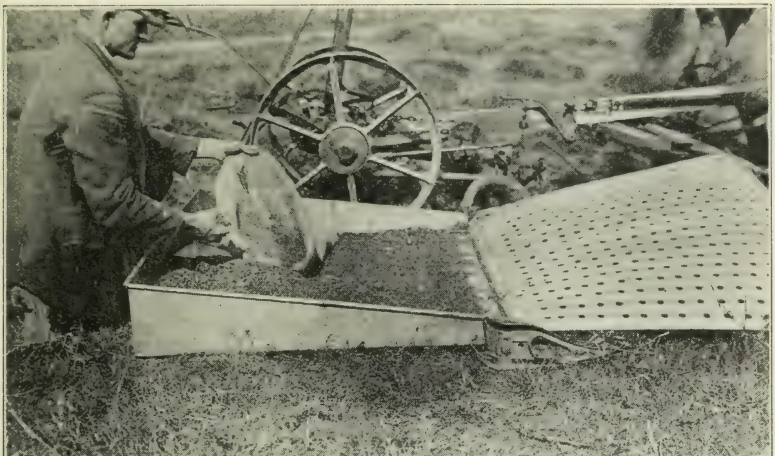
M. Plants have the general character of No. 46, but are about half its size. Begins flowering in June, and ripens a good crop of seed and dies before frost. The original selection was made in Swain County, North Carolina, at an elevation of about 4500 feet. This variety is adapted to sections having a short growing season, but will not compete with the larger varieties in other sections.

OTHER NEW AND IMPROVED VARIETIES

From time to time new varieties have been reported. About two years ago a large and improved variety was reported from South Carolina, but it has not been described. Gerald McCarthy, Botanist of the North Carolina Agricultural Experiment Station, reported in 1895 a broad-leaved variety, which he named *Lespedeza striata* var. *lata*.[8] He described it as a broad-leaved and stronger-growing variety of the common Japan clover. The two varieties were grown side by side, and the broad-leaved variety showed such superiority over the old variety that he recommended that the latter be discarded and only the former be grown. It is described as creeping and growing in flat rosettes on the ground, producing seed at the same time, and in about the same quantities as the common variety. The variety seems to have been lost. An inquiry sent to the North Carolina Station brought the reply that no such variety is now grown at the Station. The pictures in McCarthy's publication show that his variety is different from our new varieties. The broad-leaved strain has not appeared in any of our selections.

THE PLACE OF LESPEDEZA

Lespedeza, while a very useful crop plant, has limitations as well as advantages. It will not take the place of alfalfa and the clovers, cowpeas, or soybeans. It will grow, however, in many situations where the others fail. Stands can be secured under widely varying conditions. It grows well on fertile or thin soils, acid or alkaline, dry or wet; but does best, of course, on fertile and well-drained soils, with plenty of lime. It will grow on more poorly drained soils than any other common legume. It spreads rapidly and naturally into new territory, reseeding itself, which is not true of the other crops mentioned. It stands drought well, and will recover quickly after a drought. It furnishes an abundance of good pasture where the other legumes could not be depended upon. Yields of hay compare very favorably with those from the other legumes, and it requires but one cutting a season, whereas alfalfa and red



Seed Pan Opened for Removal of Seed.

Field of No. 76 Harvested for Seed. Hay Cut with Dew On and Raked into Windrows.

clover are cut twice or oftener. The harvest time is at a season when the weather is favorable for hay-curing, and other farm work is not urgent. In quality and feeding value the hay is about equal to that of alfalfa and red clover. There is no longer any doubt that lespedeza is a valuable soil improver.

On the other hand, it has certain disadvantages. It is late in developing, and is smaller than the other crops. If harvested at the time when the best hay is obtained it may fail to reseed itself, especially if the stand is very thick. A second crop is seldom obtained the same season, although enough growth may be made to reseed if the season is favorable.

Lespedeza is never a pest, as it is easily killed by cultivation.

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